3.4 WATER SUPPLY

3.4.1 INTRODUCTION

This section discusses the water supply available to the Lower Division states and Mexico under baseline conditions and the interim surplus criteria alternatives. It provides an evaluation of the effectiveness of meeting the water delivery objectives previously articulated by the Lower Division states and notes the states' contingency plans in the event of shortages. Water supply deliveries are the deliveries of Colorado River water by Reclamation to entities in the seven Basin States and Mexico, consistent with a body of documents often referred to as the *Law of the River*, as discussed in Section 1.3.4.1.

3.4.2 METHODOLOGY

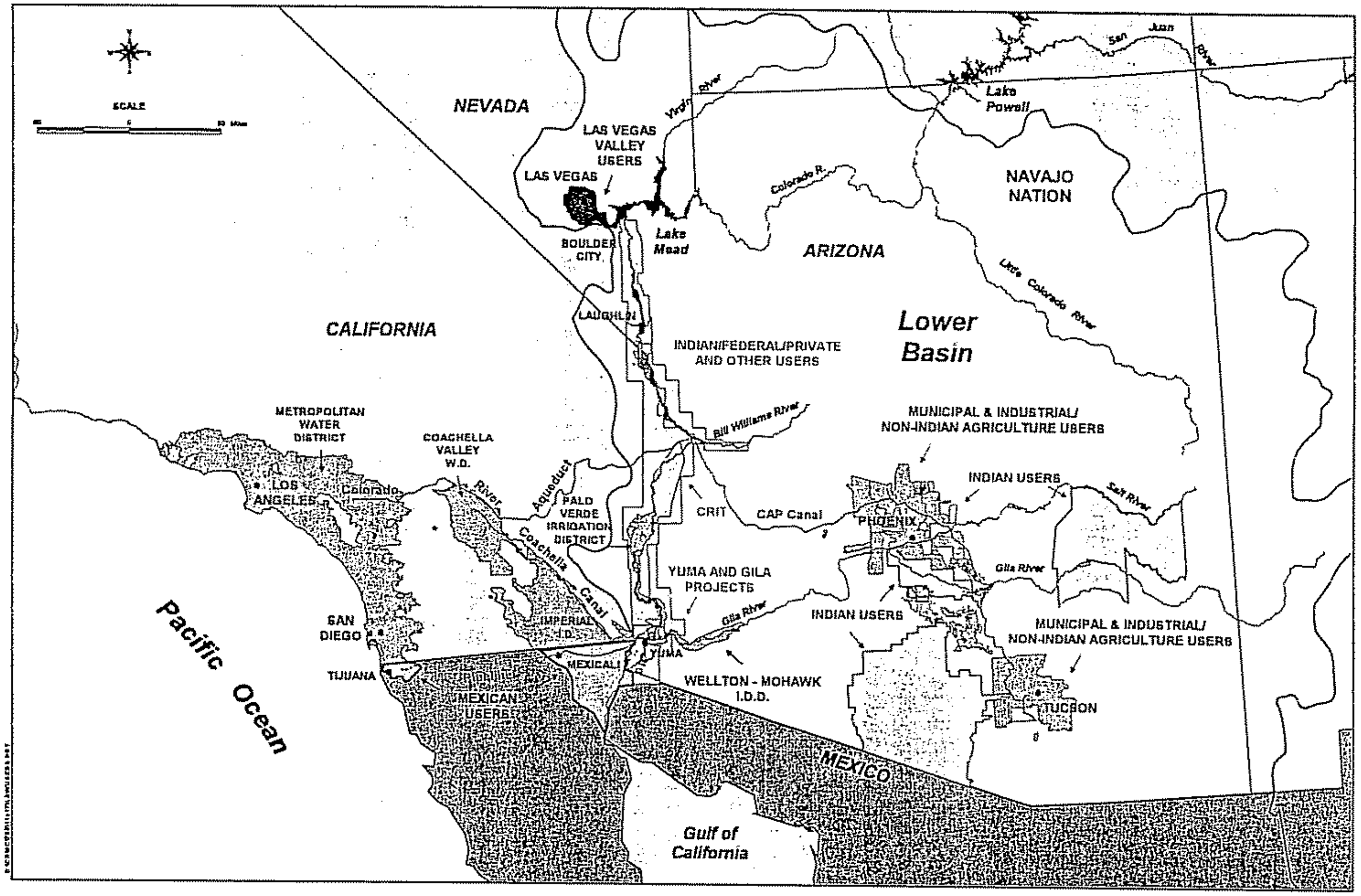
The model was used to produce estimates of future water supply deliveries for the Lower Division states and Mexico under the modeled hydrologic conditions. The modeled water demands of the Lower Division states reflect demand projections provided by the water users as described in Section 3.3.3. A copy of the demand schedules used to model the Lower Division states' depletions is included in Attachment H. The demand schedule used to model the Upper Division states' depletions is included in Attachment K.

The output from each model run included monthly and annual diversions, return flows and depletions for the Colorado River water users in af. The water supply data was analyzed using statistical methods and focused upon the comparison of the model results of the surplus alternatives to baseline conditions. See Section 3.3 for a further explanation of the modeling process.

3.4.3 AFFECTED ENVIRONMENT

The affected environment for water supply consists of the Colorado River from Lake Powell to the SIB, including the mainstream reservoirs. Geographically, the affected environment is bounded by the reservoir shorelines at maximum reservoir levels and the 100-year flood plain of the affected intervening sections of the Colorado River. This zone includes all the diversion points for water users in the Lower Division states and Mexico. Map 3.4-1 presents the water service areas in the Colorado River Lower Basin.

Map 3.4-1
Colorado River Water Service Areas in the Lower Basin



3.4.3.1 WATER USE PROJECTION PROCESS

Three Colorado River water supply conditions are recognized in the operation of the river system: surplus, normal and shortage conditions, as discussed in Section 1.3.4.1. The Basin States provided Reclamation with revised estimates of projected water use under each of the three water supply conditions for use in the modeling for this FEIS. Copies of the depletion schedules used to model the Upper and Lower Division states' demands are presented in Attachments K and H, respectively. Second level shortage amounts are computed within the model as described in Section 3.3.3.4. The states' requests are distributed among the major diversion points along the river system. The projections for normal water supply conditions reflect each state's water supply apportionment from the Colorado River.

3.4.3.2 STATE OF ARIZONA

The portions of Arizona in the Lower Basin that depend on Colorado River mainstream water consist of the following areas:

- The lower Colorado River from Lake Mead to the SIB;
- The Gila River Valley upstream from Yuma, Arizona; and
- A large area in the central part of the state served by facilities of the CAP.

Under the BCPA and the Decree, Arizona receives on annual apportionment of 2.8 maf from the Lower Division states' total of 7.5 maf.

In addition, Arizona can also use up to 50,000 afy of water pumped from Lake Powell under the State's Upper Basin apportionment. Numerous districts and other entities that divert and distribute the water administer the contractual arrangements for the use of Colorado River water in Arizona. The Central Arizona Water Conservation District (CAWCD) administers the CAP water diversions. The Director of the Arizona Department of Water Resources has state statutory authority to represent the state in Colorado River water supply matters.

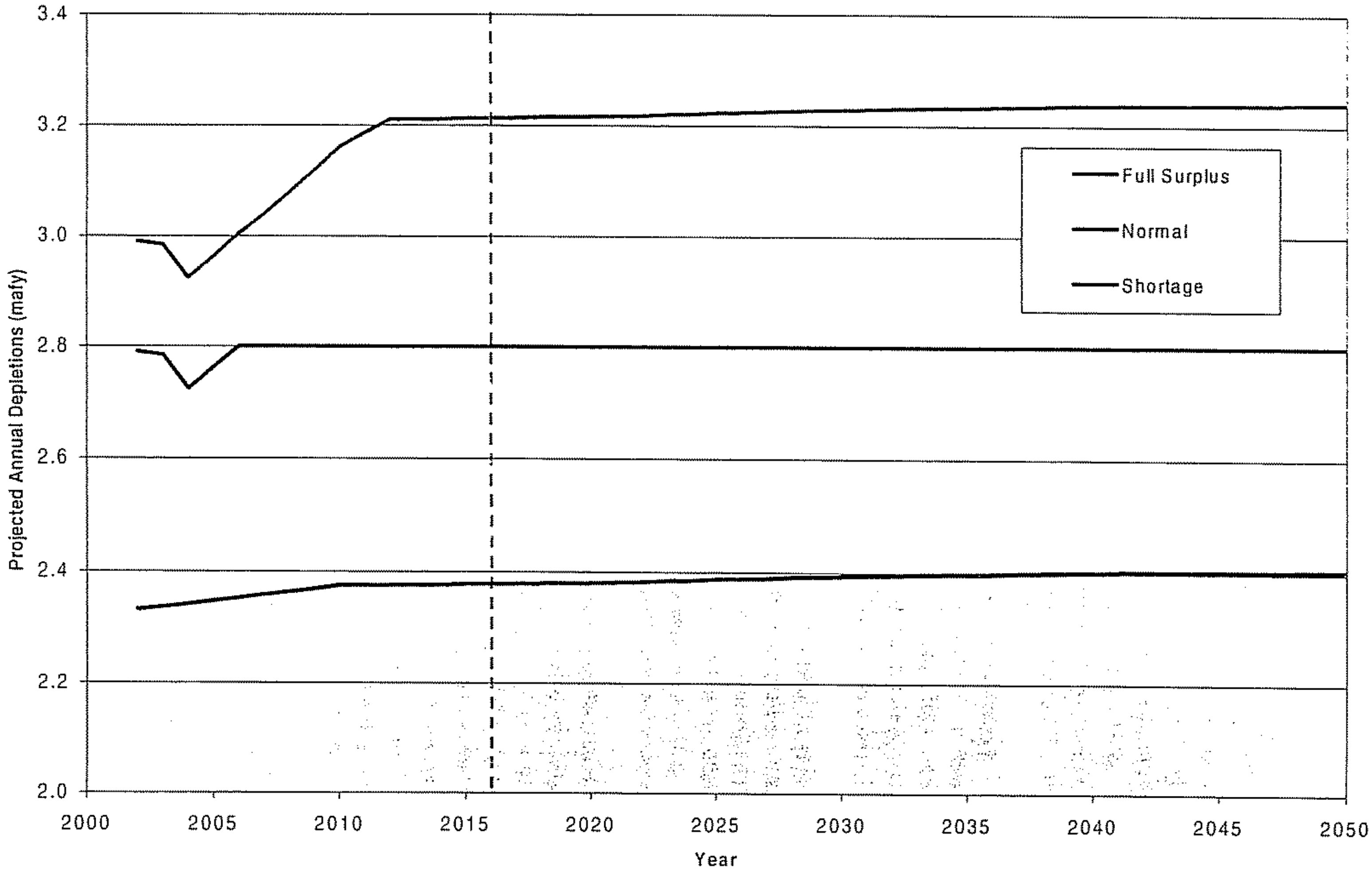
Arizona established the Arizona Water Banking Authority (AWBA) in 1996. The state legislation that authorized the AWBA states that it was created: 1) to increase Arizona's use of Colorado River water by delivering though the CAP system and storing water that otherwise would be unused by Arizona; 2) to ensure an adequate water supply to CAP municipal and industrial (M&I) users in times of shortages or disruptions of the CAP system; 3) to meet water management plan objectives of the Arizona state groundwater code; 4) to assist in settling Indian water rights claims; and 5) to provide an opportunity for authorized agencies in California and Nevada to store unused Colorado River water in Arizona for future use.

Arizona has numerous users of Colorado River water The largest diversion of water is the CAP that delivers water to contractors in the central part of the state. CAP's diversion is located at Lake Havasu. The next three largest diversions are those of the Colorado River Indian Reservation at Headgate Rock Dam and the Gila and Yuma Projects, whose diversions are located at Imperial Dam. The remaining diversions serve irrigated areas and community development along the river corridor, including lands of the Fort Mojave Indian Reservation, water used by federal agencies in Arizona, the cities of Bullhead, Lake Havasu and Parker, Mojave Valley Irrigation District and Cibola Irrigation District. A portion of the water from the river corridor is also diverted by wells located along the river.

The CAP and other fourth priority Arizona users that contracted for Colorado River water after September 30, 1968, have the lowest priority. The exceptions are lower priority contractors that contracted for unused normal year entitlement and surplus year supplies when available. Included in the CAP category are Bullhead City, Lake Havasu City, Mojave Valley Irrigation District and others. For the most part, the non-CAP contracts total 164,652 afy. The non-CAP users include present perfected rights or other rights that predate the BCPA and users that contracted before September 30, 1968.

Under shortage conditions, initial shortages in the United States would be shared between Nevada and Arizona on a four and 96 percent basis, respectively. Within Arizona, if any use of water was occurring under contracts for unused entitlement, that use would be the first eliminated under shortage conditions. Any remaining reduction in Arizona would be shared prorata among the CAP and the non-CAP holders of fourth priority entitlements. More severe shortages would result in holders of higher priority entitlements having to incur reduction in their water use. For this FEIS, the analysis of Arizona's water supply under baseline conditions and the interim surplus criteria alternatives has been limited to an analysis of the effects of water availability on total Arizona diversions. Figure 3.4-1 presents a graphical illustration of Arizona's normal, full surplus and first level shortage condition depletion schedules that were used as input for the model. These data are presented in tabular form in Attachment H.

Figure 3.4-1
Arizona Projected Colorado River Water Demand Schedules
(Full Surplus, Normal and Shortage Water Supply Conditions)



Arizona's consumptive use of Colorado River water, including that used for groundwater banking, reached its normal year entitlement of 2.8 maf in 1997. However, its consumptive use since then has been less than this amount.

As shown on Figure 3.4-1, Arizona's normal year depletion schedule is projected to reach 2.8 maf in 2006, and remains at that level thereafter. For the modeling, Arizona's unused apportionment in 2002 through 2005 was distributed to MWD (73 percent) and SNWA (27 percent). The CAP's projected normal year depletions are approximately 1.458 maf in 2002 and gradually decrease to 1.395 maf by 2050, which represent approximately one-half of the state's total normal demand. The demands of Arizona's non-CAP users meanwhile increase towards their full apportionment amount as time progresses making up the balance of Arizona's normal 2.8 maf apportionment.

The state's projected full surplus depletions increase from 2.99 maf in 2002 to approximately 3.24 maf in 2050. The projected CAP surplus condition demand rises steadily from 1.658 maf to approximately 1.835 maf in 2012. Thereafter, the CAP surplus condition depletion schedule remains flat at approximately 1.835 maf. First level shortage condition depletions for Arizona increases from 2.332 maf in 2002 to 2.405 maf by 2050.

The modeled Colorado River water deliveries under the baseline conditions and surplus alternatives assumed that all Arizona shortages would be assigned to the CAP, as discussed in Section 3.3.3.4. Although it is recognized that under the current Arizona priority framework there would be some sharing of Arizona shortages between the CAP and users at the same priority, modeling at this level of detail was not necessary to analyze deliveries on a statewide basis.

Arizona's basic strategy for meeting short-term shortages in CAP M&I supply centers on reduced uses for recharge, reduced agricultural deliveries and an increased use of groundwater. In addition to naturally occurring groundwater, Arizona has established a groundwater bank and it is currently actively storing CAP water that is excess to its current needs for future withdrawal. As discussed above, the AWBA administers the groundwater bank. Groundwater banking is occurring with the intent of providing a source for withdrawal during periods when the amount of Colorado River water available for diversion under the CAP priority is curtailed by shortage conditions. Additionally, CAWCD has stored a substantial amount of CAP water in central Arizona.

It is projected that CAP water will be used for groundwater recharge until about 2040 under normal and surplus conditions. This use will be terminated first in case of shortage. For other interim and long term contract users, agriculture has the lowest priority. Therefore, irrigation users will be reduced before CAP M&I or Indian users in case of shortage conditions. Most irrigation users have rights to pump groundwater as a replacement supply. The increased use of the groundwater supplies and the management of the groundwater basins are expected to be consistent with the state's groundwater management goals.

When CAP diversions are limited to 1.0 maf during first-level shortage conditions, the impact before year 2020 would be to both groundwater recharge and agricultural users. After 2020, CAP M&I users would also be impacted by shortage conditions.

3.4.3.3 STATE OF CALIFORNIA

The Colorado River supplies about 14 percent of the water used in California by agriculture, industry, commercial businesses and residential customers. All of the Colorado River water used by California is used in the southern California region. Colorado River water is by far the most important source of water for southern California, accounting for over 60 percent of its water supply. During the last several years, the Colorado River has supplied up to 5.2 maf of the 8.4 maf of water used annually in southern California.

Under the BCPA and the Decree, 7.5 maf of Colorado River water is apportioned for consumptive use in the Lower Division states (California, Nevada and Arizona). In 1964, a United States Supreme Court decree established California's normal apportionment of 4.4 maf from within the Lower Division states' 7.5 maf apportionment. The 1979 and 1984 Supplemental Decrees also awarded present perfected water rights to Indian reservations along the Colorado River. The 1964 Decree granted California, Arizona and Nevada respectively 50 percent, 46 percent, and four percent shares of any surplus water the Secretary determines to be available for use by the Lower Division states.

In California, a priority system for the principal parties that claimed rights to Colorado River water was established by the *California Seven-Party Agreement of August 31, 1931*. The priority system allows water apportioned but unused by a senior priority holder to cascade down to the next lower priority. The *Seven-Party Agreement* limits a priority holder's use of this water to beneficial use exclusively on lands within the priority holder's service area. The water transfers that are being proposed to be implemented under California's *Colorado River Water Use Plan* will work within the framework of the *Seven-Party Agreement* and within the framework of the agreements that are executed to carry out those transfers.

Agriculture and present perfected rights have highest priority to about 90 percent of California's entitlement. The balance goes to the MWD, which provides wholesale water service to most of the communities within the southern California coastal plain. California's largest agricultural water agencies that rely on Colorado River water include the IID, Palo Verde Irrigation District (PVID) and the Coachella Valley Water District (CVWD).

Three major structures divert water from the Colorado River to California. Parker Dam impounds Lake Havasu, which supplies water for MWD's Colorado River Aqueduct on the California side of the state line and for the Central Arizona Project on the Arizona side of the state line. Palo Verde Diversion Dam supplies water to PVID's canal system. Imperial Dam diverts water to the All American Canal on the California side of the state line and to the Gila Gravity Main Canal on the Arizona side of the state line. The AAC is used to deliver water to the Yuma Project, IID and the CVWD.

California has relied on the Secretary's release of unused Nevada and Arizona Colorado River apportionments in accordance with Article II(B)(6) of the Decree for more than three decades. In recent years, Nevada and Arizona depletions have approached their apportionment amounts as a result of the completion of the CAP and rapid population growth in these states. Additionally, Arizona has started to bank its water (such as by groundwater storage) to protect against future shortages. As a result, there is currently not enough Nevada and Arizona unused apportionment to meet California's demand. Since 1996, California has received as much as 800,000 af above its annual 4.4 maf normal apportionment due to determinations by the Secretary of surplus conditions on the Colorado River through the AOP process.

The California Department of Water Resources projects that over the next several decades, California's overall demand for water will continue to increase. Urban demand is expected to outweigh projected declines in agricultural demand. For example, the Department's 1993 California Water Plan projected that urban water demand will increase by 60 percent from 1990 to 2020. However, California's ability to access Colorado River water beyond its normal apportionment may be limited for the following two reasons:

- Since Arizona and Nevada will be using their normal apportionment's, California's access to any substantial amount of water above its normal apportionment will depend on surplus determinations by the Secretary on a year-by-year basis. Under current Colorado River system management practices, such determinations are not certain, as they depend on conditions which change each year—namely snowpack runoff and reservoir storage.

- Even with a surplus determination, California's access is limited by the capacity of its delivery systems. Currently, the existing delivery system to urban users—the Colorado River Aqueduct—is operating at near capacity (approximately 1.3 maf per year).

If the amount of Colorado River water available for use in California was limited to the 4.4 maf normal apportionment, the immediate impact would fall mainly on the MWD because much of the allocation to California above normal apportionment now goes to urban users serviced by MWD. MWD (or its customers) would have to look to: 1) other California users of Colorado River water, namely the agriculture agencies, or 2) other sources—such as northern California water supplies—for about 700,000 af of the approximate two maf of MWD's normal annual water deliveries, which ranged between 1.5 maf and 2.6 maf during the 1990s.

California faces other issues that may impact the quantity or quality of the supply of Colorado River water to certain users. In particular, listing of additional endangered bird and fish species could reduce the amount of water available for non-environmental purposes. Also, Colorado River salinity control projects could impact the quantity and quality of future Colorado River water. Both the type of crops produced (high market value crops generally require water that is low in salinity) and the quality of southern California drinking water could change.

The Colorado River Board of California developed a plan for California to live within its normal apportionment of 4.4 maf. The Board's draft plan was previously referred to as the California 4.4 Plan (dated August 11, 1997) and addressed various water supply management issues that are focused on changes in the use, supply or transfer of Colorado River water. The draft plan was updated, renamed and re-released in May 2000 as the *California Colorado River Water Use Plan* (CA Plan). The CA Plan relies first on a variety of intrastate measures that either conserve water or increase water supplies. The plan also relies on measures that would make extra water available to California. (A discussion of the Colorado River Board's CA Plan and the various water supply and water resources management measures contemplated therein are presented in Section 1.4.1.)

California's use of Colorado River water reached a high of 5.4 maf in 1974 and has varied from 4.5 to 5.2 maf per year over the past 10 years. Limiting California to 4.4 maf per year would reduce California's annual water supply by approximately 800,000 afy. All or most of this reduction will be borne by MWD. While the water supply analysis under the FEIS is focused on the total California depletions, the assumption is made that the surplus deliveries that may become available would be managed and distributed by and between the California users in accordance with the proposed provisions of the CA Plan, the corresponding "Quantification Agreement" and associated cooperative programs. Most of these cooperative programs are between MWD or one of its member agencies and the agricultural water agencies. Under these programs, MWD will be able to use its basic Colorado River water apportionment plus water made available under water conservation and groundwater storage programs. These programs include the following:

- **Coachella Groundwater Storage Program** - Cooperative program with the Desert Water Agency and the CVWD that exchanges their State Water Project (SWP) entitlements for MWD's Colorado River water and provides storage of Colorado River water for future extraction by these two agencies.

- **Water Conservation Program with Imperial Irrigation District** - MWD and the IID entered into a water conservation agreement in December 1988. The agreement called for IID to implement various projects to conserve water including improving its water distribution system and on-farm management of water.

- **Test Land Fallowing Program in the Palo Verde Valley** - MWD and the PVID implemented a two-year test land-fallowing program from August 1, 1992 through July 31, 1994.

- **Demonstration Project on Underground Storage of Colorado River Water in Central Arizona** - Under a cooperative program with the CAP, MWD has placed 89,000 af and the SNWA has placed 50,000 af of unused Colorado River water in underground storage (groundwater banking) in central Arizona.

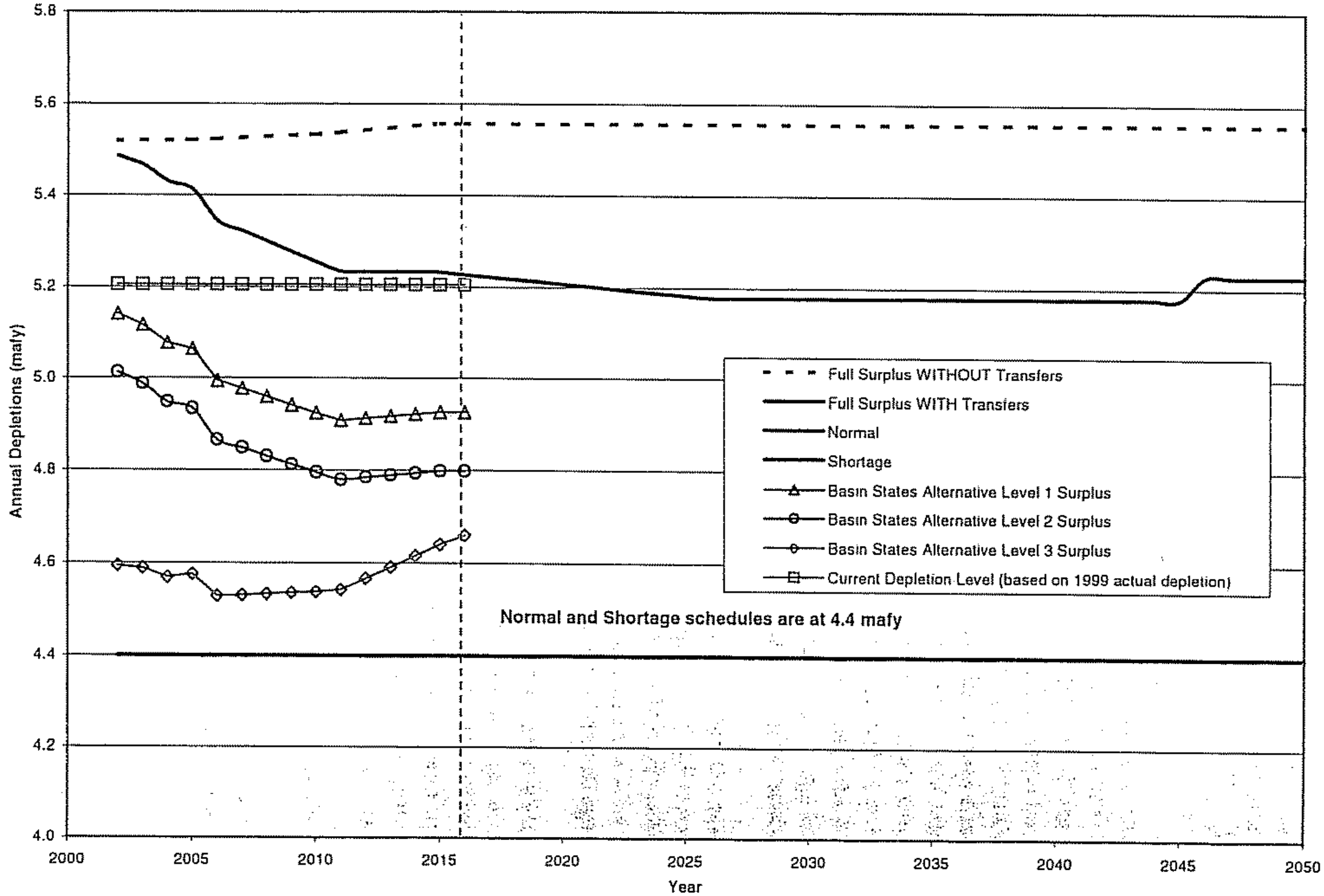
- **Agricultural-to-Urban Intrastate Water Transfers** – The SDCWA and IID have negotiated an agreement by which IID will transfer (sell) agricultural water conserved through various conservation and efficiency programs to SDCWA for urban use – where demand is growing. The agreement contemplates transfer of up to 200,000 afy. A number of bills have been introduced in the California Senate that attempt to address this and other similar intrastate water transfers, including SB 1011 (Costa), SB 1082 (Kelley), SB 1335 (Polanco) and AB 554 (Papan). To date, the legislature has enacted only SB 1082 which would facilitate a transfer of water between the IID and the SDCWA.

Figure 3.4-2 presents a graphical illustration of California's full surplus, normal and first level shortage demand schedules that were used as input to the model. Two full surplus depletion schedules are shown (with and without transfers). The sensitivity analysis that evaluated a baseline condition without intrastate transfers is provided in Attachment L. These two surplus schedules consider the fact that California anticipates a continued need for surplus water, when available, in order to implement the conjunctive use programs (e.g., groundwater banking) that will assist California in reducing its projected Colorado River depletion toward its normal apportionment of 4.4 mafy.

However, California's full surplus schedule that considers the proposed intrastate water transfers is substantially less than the full surplus schedule without the transfers over time. This reflects the additional cooperative programs that would increase the amount of water transferred from agricultural agencies to MWD. Therefore, as a result of the Quantification Agreement, the cooperative programs, and the proposed increased intrastate transfers, the full surplus depletion schedules for California are reduced while at the same time, allowing MWD to continue to meet its users' needs.

As illustrated by the graph, the Basin States Alternative provides an opportunity to manage the surplus deliveries coincident with the management of Lake Mead water levels while at the same time, providing a structure whereby total deliveries to California are reduced. These reductions are significant when compared to California's current depletion level of 5.2 mafy, also shown on Figure 3.4-2. Both California's normal and Level 1 shortage condition water depletion schedules are at 4.4 maf throughout the period of analysis.

Figure 3.4-2
California Projected Colorado River Water Demand Schedules
(Full Surplus, Normal and Shortage Water Supply Conditions)



3.4.3.4 STATE OF NEVADA

The portion of Nevada that depends on Colorado River water is limited to southern Nevada, primarily the Las Vegas Valley and the Laughlin area further south. The Colorado River Commission and SNWA manages Nevada's Colorado River water supply. The SNWA coordinates the distribution and use of the water by its member agencies whose systems provide retail distribution.

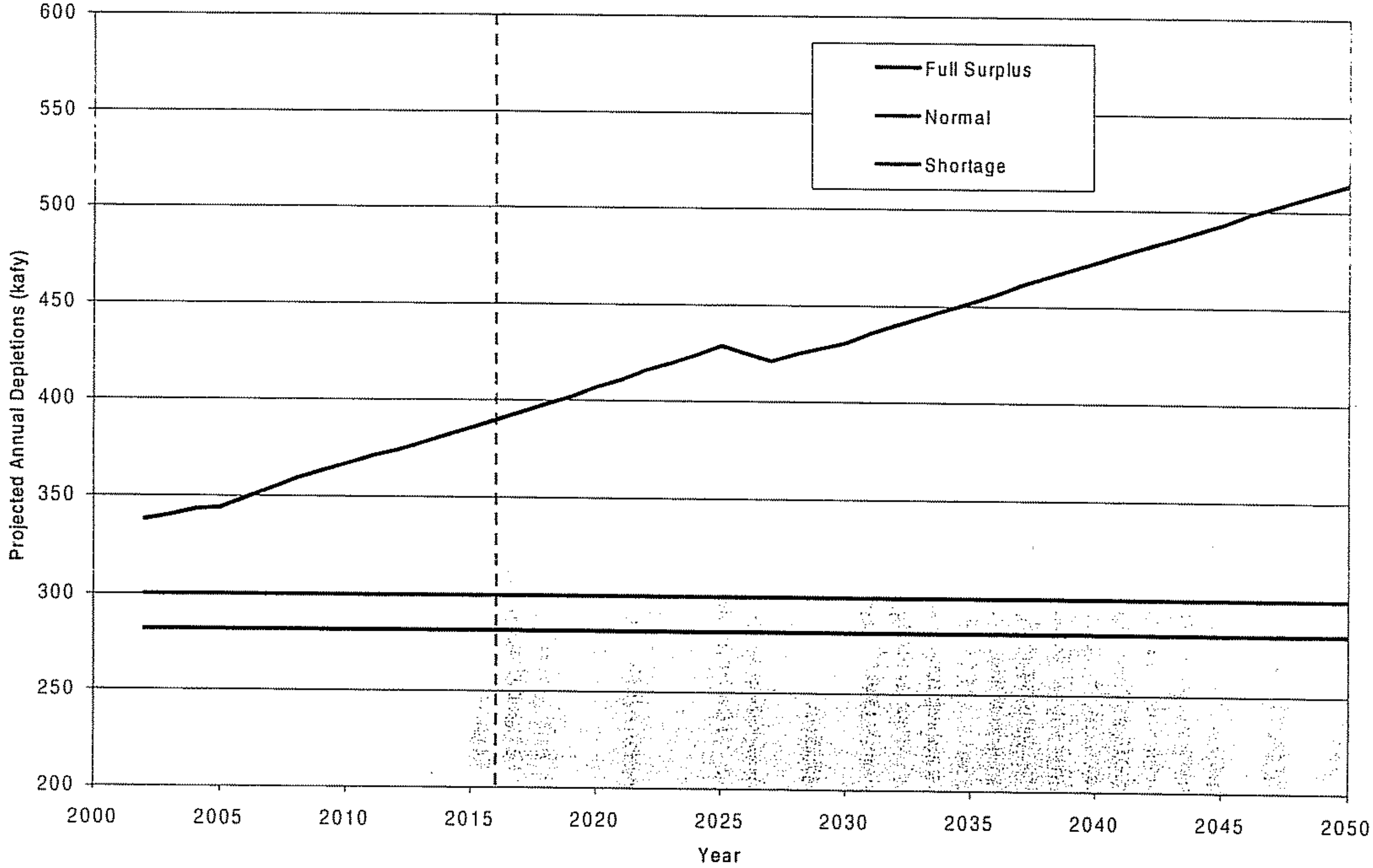
Nevada has five principal points of diversion for Colorado River water. The largest of these is the Las Vegas Valley that pumps water from Lake Mead at Saddle Island (on the west shore of the lake's Boulder Basin) through facilities of SNWA. The water is pumped at two adjacent pumping plants. The Lake Mead minimum water surface elevations for each intake are 1050 feet msl and 1000 feet msl, respectively. The pumped water is treated before being distributed to the Las Vegas Valley and to Boulder City water distribution systems. Three other diversion points are downstream of Davis Dam. They serve the community of Laughlin, Southern California Edison's coal fired Mohave Generating Station and uses on that portion of the Fort Mojave Indian Reservation lying in Nevada. The fifth diversion consists of water used by federal agencies in Nevada, primarily the National Park Service and its concessionaires at various points on lakes Mead and Mohave.

Nevada's current Colorado River water demand is on the threshold of reaching its Colorado River normal water apportionment under the BCPA and the Decree of 300,000 afy. SNWA depletions represent approximately 90 percent of this amount. Figure 3.4-3 presents a graphical illustration of the full surplus, normal and first level shortage demand schedules for Nevada that were used as input to the model.

Nevada's water demand projections for full surplus years rise steadily from a current value of approximately 338,000 af to approximately 514,000 af in 50 years, the end of the period of analysis for this FEIS. Projected depletions under shortage conditions are approximately 282,000 afy over the period of analysis, reflecting the fact that Nevada's reduction in consumptive use of Colorado River water is four percent of the total shortage during shortage years.

SNWA's Integrated Resource Plan calls for optimizing both the use of Colorado River water and the use of the Las Vegas Valley shallow aquifer before developing water from additional sources, including the lower Virgin River and Muddy River. The SNWA has been supporting groundwater recharge in the Las Vegas Valley through facilities of member agencies. The artificial recharge of Colorado River water into the Las Vegas Valley groundwater basin is intended to help meet summer peak demands, provide an interim future water supply and stabilize declining groundwater tables. Water agencies in the valley will be able to withdraw water to meet temporary shortfalls in supply. However, such withdrawals would be coupled with the opportunity for replenishment of the aquifer.

Figure 3.4-3
Nevada Projected Colorado River Water Demand Schedules
(Full Surplus, Normal and Shortage Water Supply Conditions)



Nevada also proposes to bank water in Arizona through arrangements with the AWBA using available groundwater storage capacity as described above in the discussion of alternate supplies for Arizona.

3.4.3.5 UPPER BASIN STATES

The depletions for the Upper Basin states were developed and submitted by the Upper Colorado River Commission (Commission) to Reclamation in December 1999. These depletions were then modified in coordination with the Commission to include updated Indian Tribe depletions provided by Keller-Bliessner Engineering, acting on behalf of the Indian Tribes with Colorado River water rights (see Attachment Q). Figure 3.3-4 shows that the Upper Basin depletions are approximately at 4.273 maf in 2002 and increase gradually to approximately 5.325 maf by 2050. These depletions do not include the evaporation losses that occur within the Upper Basin and that are estimated to be approximately 574,000 afy. The Upper Division depletion schedule that includes the estimated evaporation losses are presented in tabular form in Attachment K. The modeled depletions as shown on Figure 3.3-4 and presented in Attachment K are consistent with the Upper Division states' apportionment of Colorado River water.

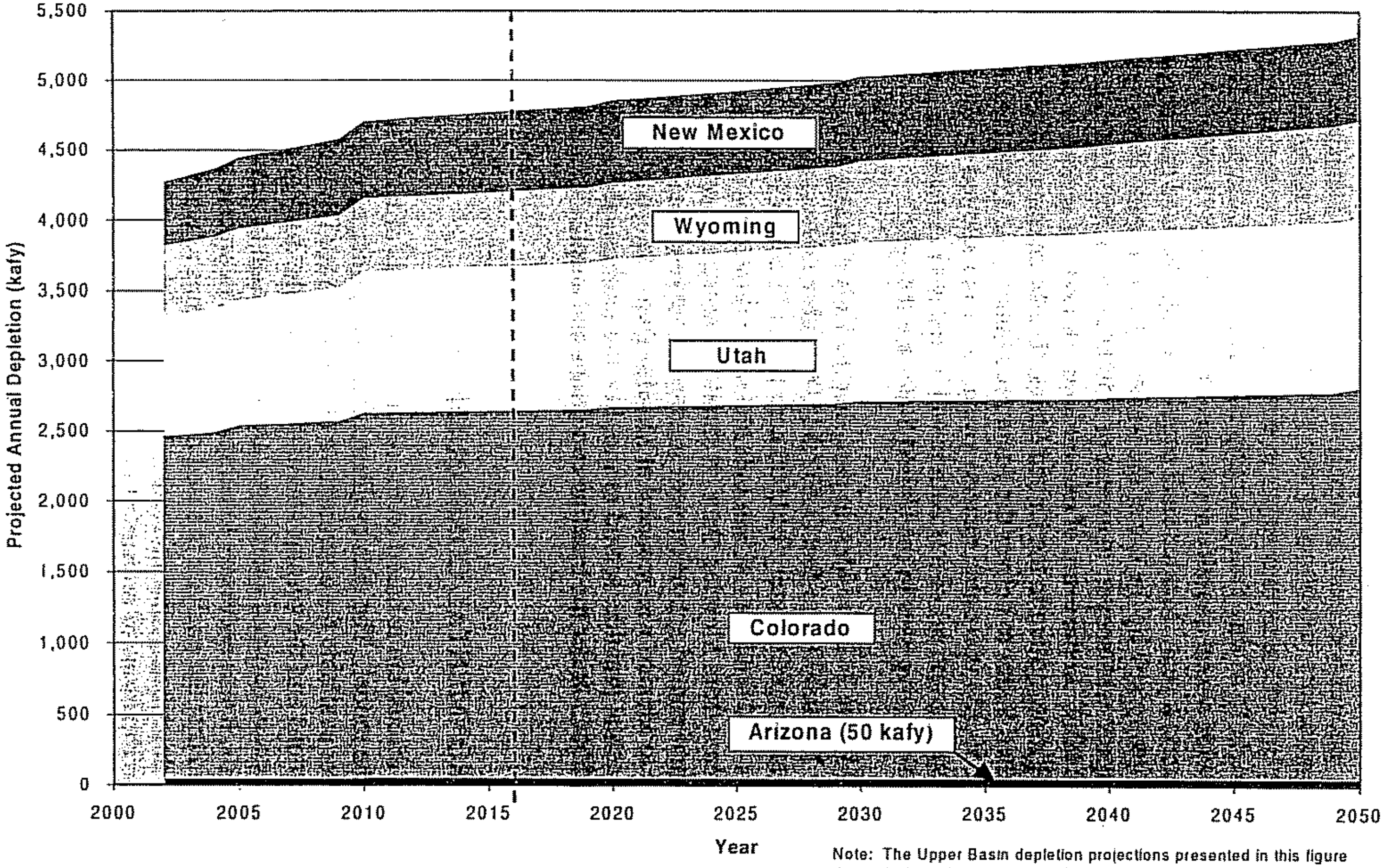
3.4.3.6 MEXICO

As discussed earlier in Section 1.3.2.2.3, Mexico has a Treaty entitlement to Colorado River water. This entitlement is set forth in Article 10 of the Treaty that states the following:

"Of the waters of the Colorado River, from any and all sources, there are allotted to Mexico:

> (a) A guaranteed annual quantity of 1,500,000 af (1,850,234,000 cubic meters) to be delivered in accordance with the provisions of Article 15 of this Treaty.

Figure 3.4-4
Upper Basin Depletion Projections
(Based on 1998 Depletion Schedule)



Note: The Upper Basin depletion projections presented in this figure do not include the evaporation losses that are estimated to be approximately 574,000 afy.

(b) Any other quantities arriving at the Mexican points of diversion, with the understanding that in any year in which, as determined by the United States Section, there exists a surplus of waters of the Colorado River in excess of the amount necessary to supply uses in the United States and the guaranteed quantity of 1,500,000 af (1,850,234,000 cubic meters) annually to Mexico, the United States undertakes to deliver to Mexico, in the manner set out in Article 15 of this Treaty, additional waters of the Colorado River system to provide a total quantity not to exceed 1,700,000 af (2,096,931,000 cubic meters) a year. Mexico shall acquire no right beyond that provided by this subparagraph by the use of the waters of the Colorado River system, for any purpose whatsoever, in excess of 1,500,000 af (1,850,234,000 cubic meters) annually. In the event of extraordinary drought or serious accident to the irrigation system in the United States, thereby making it difficult for the United States to deliver the guaranteed quantity of 1,500,000 af (1,850,234,000 cubic meters) a year, the water allotted to Mexico under subparagraph (a) of this Article will be reduced in the same proportion as consumptive uses in the United States are reduced."

Additionally, Minute 242 provides, in part, that the United States will deliver to Mexico approximately 1,360,000 acre-feet (1,677,545,000 cubic meters) annually upstream of Morelos Dam and approximately 140,000 acre-feet (172,689,000 cubic meters) annually on the land boundary at San Luis and in the limitrophe section of the Colorado River downstream from Morelos Dam. It should be noted that while a portion of Mexico's 1.5 maf annual apportionment is actually delivered below Morelos Dam, the entire delivery to Mexico was modeled at Morelos Dam. This basic assumption, while different than actual practice, served to simplify and facilitate the analysis of water deliveries to Mexico under the baseline conditions and surplus alternatives.

3.4.4 ENVIRONMENTAL CONSEQUENCES

The following discussion is based on the results of analysis of water supply data generated by the model. The data evaluated consisted principally of data relating to the amount of water available for consumptive use in the Lower Division states under baseline conditions and the surplus alternatives during the 50-year period of analysis. Because differences between alternatives are at times small in relation to the quantities and time periods, it was necessary to compare the data in precise terms. However, it should be noted that the analysis is based on assumptions of water supply and operation conditions, as described earlier in Section 3.3, and that the results described below represent approximations of probable future conditions that become increasingly uncertain over time.

The time period for the analysis is 2002 through 2050. The analysis is based on depletion schedules for those years provided by the states and Tribes. Protection was provided for the water level of Lake Mead at elevation 1083 feet msl. As discussed earlier in Section 3.3, the elevation of 1083 feet msl is assumed to be the lower elevation at which the Hoover Powerplant can produce power efficiently.

The results are portrayed graphically in two ways As discussed earlier in Section 3.3, the modeling process involved making 85 separate runs (traces) which were then examined for the range of water supply available in a given year under baseline conditions and the alternatives. One way that these results can be portrayed graphically is to plot the 90th percentile values (meaning that 90 percent of the values produced by the model were less than shown), the 50th percentile values (the median value) and the 10th percentile values (that 10 percent of the values produced by the model were less than shown). Plots of the maximum and minimum depletion values produced by the model for any given year were added to this "90-50-10" array. The plots for the annual depletions for the Lower Division states and Mexico under baseline conditions are presented in this section. The plots that depict the annual depletions under each of the five surplus alternatives are included in Attachment O.

A second way that the results are portrayed is derived by first ranking all the values for the entire interim surplus criteria period (2002 through 2016) and the subsequent period (2017 through 2050). The depletion values can then be plotted versus the percent of values that are greater than or equal to. This type of plot provides a cumulative distribution of the respective state's depletion and allows for a generalized comparison of the water supply available under baseline conditions and the surplus alternatives, for each period of time.

An important modeling assumption needs to be restated to provide a better understanding of the model results for the alternatives. The interim surplus criteria used for the Basin States, Flood Control, Six States, California and Shortage Protection alternatives become null and void after year 2016. At year 2017, the operating criteria for these surplus alternatives revert to a process that approximates the baseline conditions (modeled as the 70R surplus strategy). The criteria used to model the baseline conditions is effective throughout the 50-year period of analysis.

3.4.4.1 State of Arizona

This section presents the simulated water deliveries to Arizona under the baseline conditions and surplus alternatives. The analysis of Arizona's water supply concentrated on total Arizona water depletions.

3.4.4.1.1 Baseline Conditions

The water deliveries to Arizona are projected to fluctuate throughout the 50-year period of analysis reflecting variations in hydrologic conditions The 90th, 50th and 10th percentile ranking of modeled water deliveries to Arizona under the baseline conditions are presented in Figure 3.4-5

With the exception of the first year modeled (2002), the 90th percentile line coincides with Arizona's depletion schedule during full surplus water supply conditions. As indicated by this 90th percentile line, the probability that the baseline conditions would provide Arizona's full surplus depletion schedule is at least 10 percent throughout the 50-year period of analysis.

The 50th percentile line represents the median annual depletion values. This 50th percentile line generally coincides with Arizona's projected depletion schedule under normal water supply conditions through year 2026 (see Figure 3.4-1). After 2026, the median values drop to approximately 2.39 maf and remains at approximately that level for the remainder of the analysis period. As previously noted and as reflected by the graph, Arizona's demands are not anticipated to reach its 2.8 maf entitlement until 2006.

As noted in Section 3.4.3.2, under shortage conditions, Arizona would bear 96 percent of the reduction and Nevada would bear four percent. In Arizona, the reduction would be shared prorata among CAP and non-CAP holders of fourth priority entitlements. To simplify the modeling process, the model sets the CAP's shortage condition deliveries at 1.0 maf when the Lake Mead water level is between elevation 1000 feet msl and the assumed shortage protection line as discussed in Section 3.3.3.4. This modeling assumption kept Arizona's annual deliveries above 2.3 maf until further cuts to the CAP were necessary to maintain the Lake Mead water level above the 1000 feet msl elevation (a Level 2 shortage condition). Under the baseline conditions, deliveries to Arizona below 2.3 maf were not observed to occur during the 15-year interim surplus criteria period. However, deliveries below 2.3 maf were observed during years 2017 to 2050 and occurred less than five percent of the time.

Figure 3.4-5
Arizona Modeled Annual Depletions Under Baseline Conditions
90th, 50th and 10th Percentile Values

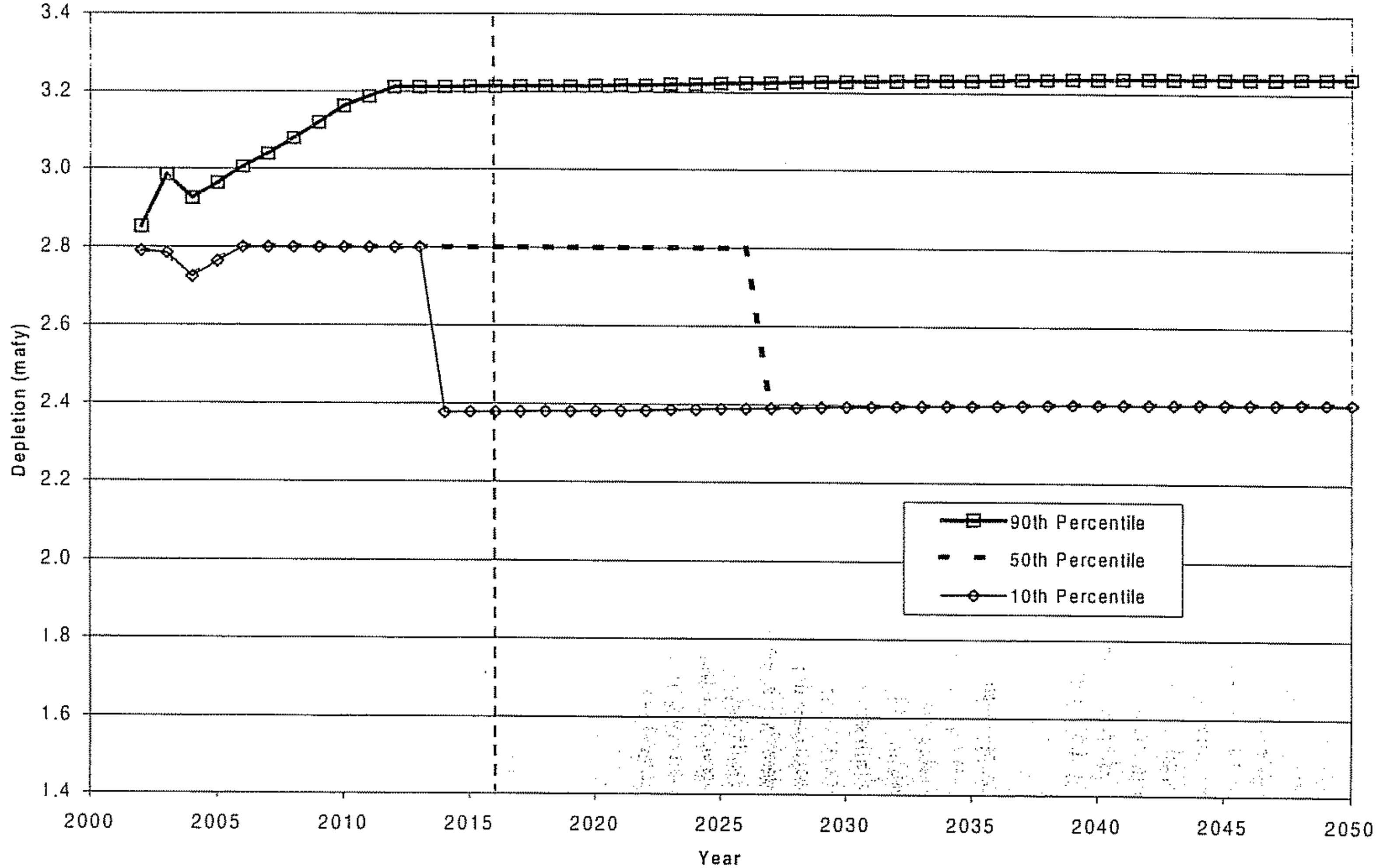


Figure 3.4-6 provides a comparison of the cumulative distribution of Arizona's depletions under the surplus alternatives to those of the baseline conditions during the interim surplus criteria period (years 2002 to 2016). This type of graph is used to represent the frequency that annual deliveries of different magnitudes occur in the respective period. The results presented in Figure 3.4-6 indicate a 96 percent probability that Arizona's depletions would meet its normal depletion schedule during this period under the baseline conditions. The probability that Arizona would receive surplus condition deliveries during this period was approximately 29 percent. The maximum surplus condition depletions under the baseline conditions were 3.213 maf during this period. The probability that Arizona would receive shortage condition deliveries was less than four percent. The minimum shortage condition depletion was 2.375 maf.

Figure 3.4-7 provides a comparison of the cumulative distribution of the water deliveries to Arizona under the surplus alternatives to those of the baseline conditions for the 34-year period (years 2017 to 2050) that would follow the interim surplus criteria period. The results presented in Figure 3.4-7 indicate a 50 percent probability that water deliveries to Arizona would meet its normal depletion schedule during this period under the baseline conditions. The probability that Arizona would receive surplus condition deliveries during this same period under the baseline conditions was approximately 21 percent. The maximum surplus condition depletions under the baseline conditions were 3.24 maf during this period. The probability that Arizona would receive shortage conditions deliveries was approximately 50 percent. The minimum shortage condition depletion was 1.596 maf, representing second level shortage conditions that occurred less than five percent of the time during this period.

Figure 3.4-6
Arizona Modeled Depletions
Comparison of Surplus Alternatives to Baseline Conditions
Years 2002 to 2016

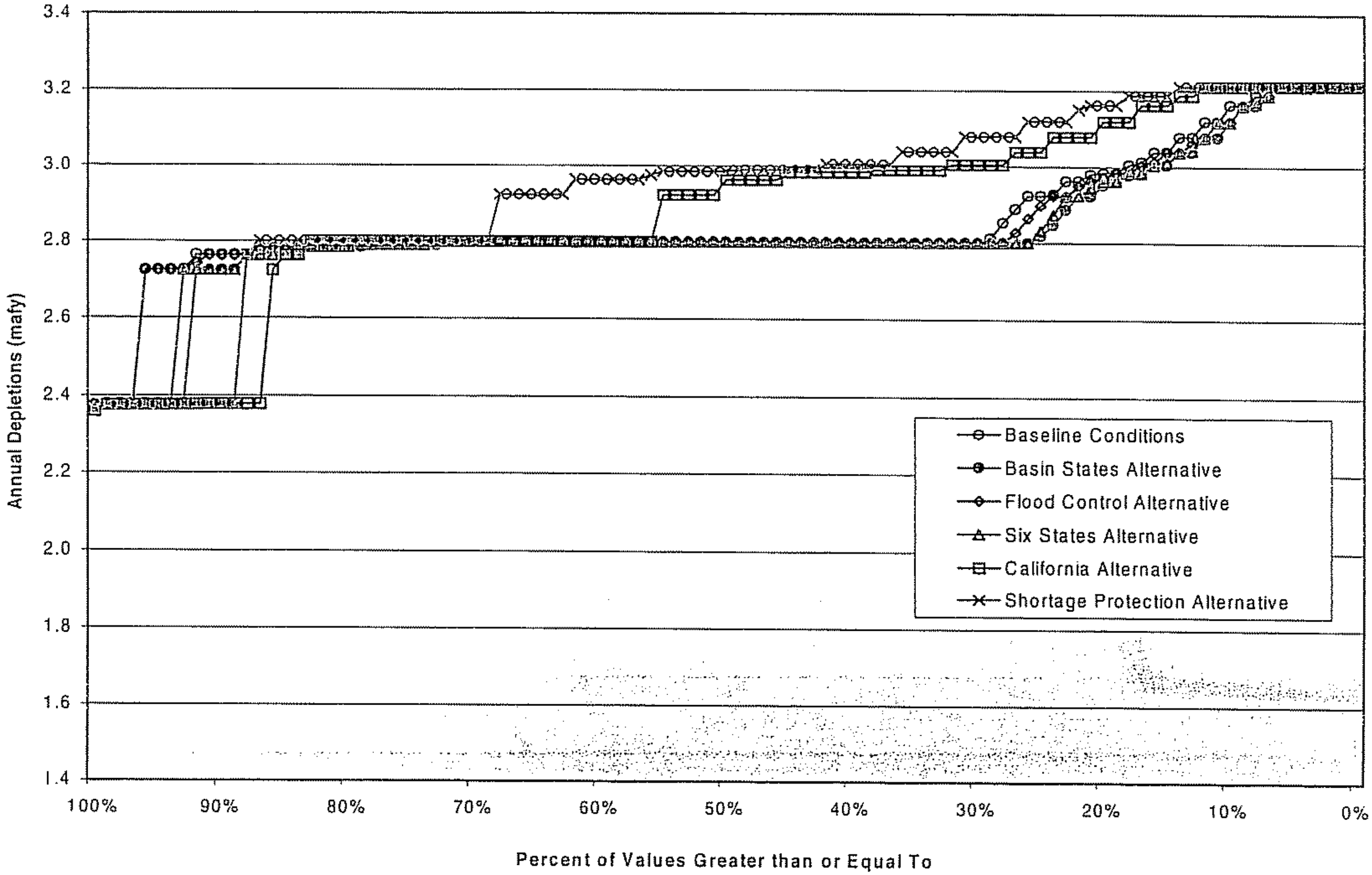
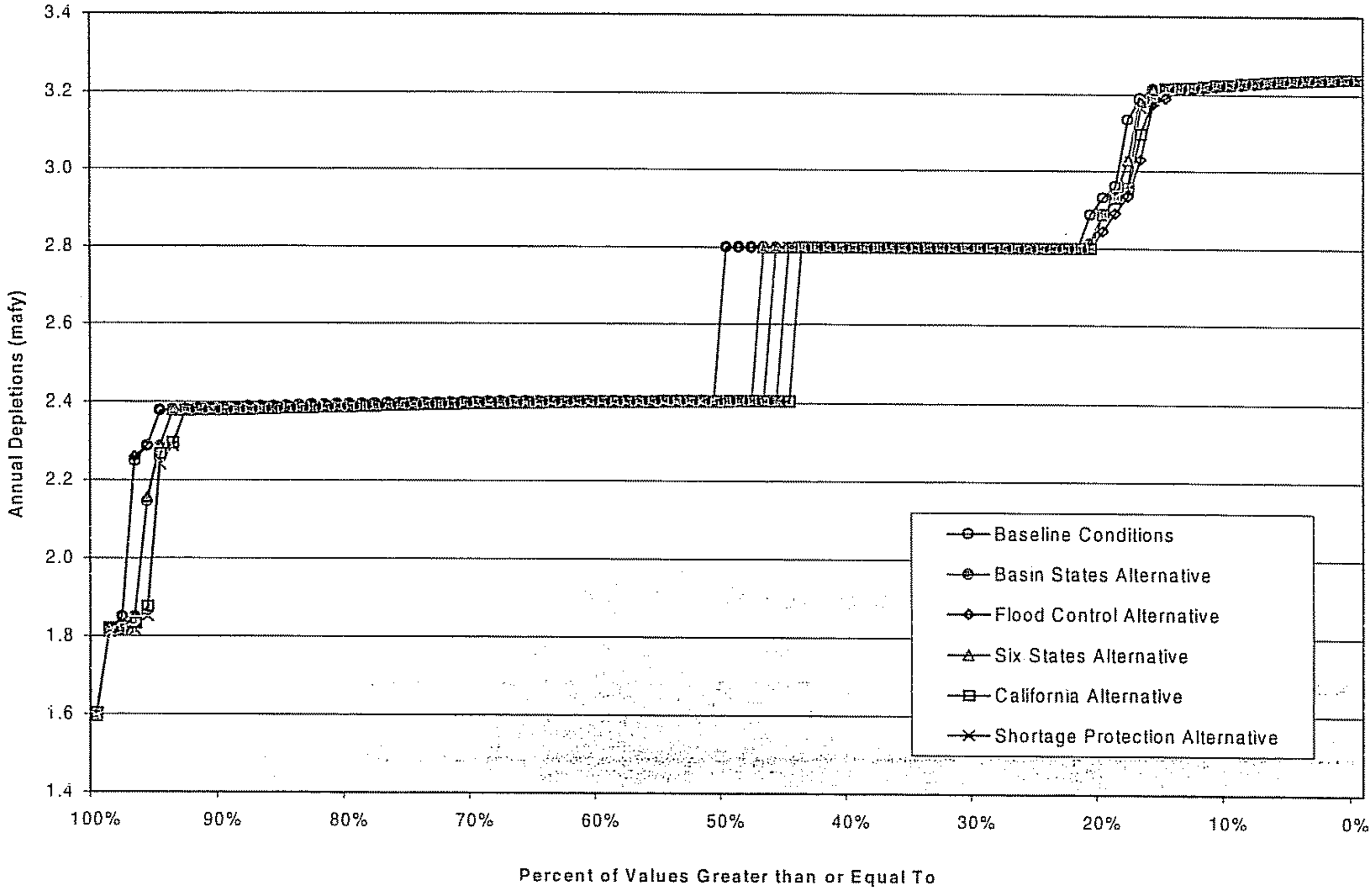


Figure 3.4-7
Arizona Modeled Depletions
Comparison of Surplus Alternatives to Baseline Conditions
Years 2017 to 2050



3.4.4.1.2 Comparison of Surplus Alternatives to Baseline Conditions

Figure 3.3-8 provides a comparison of the 90th, 50th and 10th percentile values for Arizona's modeled depletions under the baseline conditions to those of the surplus alternatives. As noted in Figure 3.4-8, there is little difference in the 90th percentile lines resulting from the surplus alternatives to those of the baseline conditions. The 90th percentile lines generally coincide with Arizona's surplus depletion schedule.

The 50th percentile lines for the baseline conditions, Basin States, Flood Control and Six States alternatives are essentially the same during the interim surplus criteria period and coincide with Arizona's normal depletion schedule. The 50th percentile lines for the California and Shortage Protection alternatives are identical to each other during the initial eight years and coincide with Arizona's surplus depletion schedule. The 50th percentile line for the Flood Control Alternative continues to coincide with the normal depletion schedule through year 2011. After 2011, the 50th percentile lines for the baseline conditions and all surplus alternatives are the same until 2023. Thereafter, the median values for the baseline conditions and surplus alternatives begin to fall due to increasing probability of the Level 1 shortages

The 10th percentile lines for the baseline conditions and the surplus alternatives are essentially at or above Arizona's normal depletion schedule through year 2009. In 2010, the California and Shortage Protection alternatives drop to the Level 1 shortage depletion values followed by the Basin States and Six States alternatives and finally in year 2013, the baseline conditions and Flood Control alternatives. Thereafter, the 10th percentile lines for the baseline conditions and the surplus alternatives remain at this level through 2050.

Figures 3.4-6 and 3.4-7 presented comparisons of the cumulative distribution of Arizona's depletions under the surplus alternatives to those of the baseline conditions during the interim surplus criteria period (years 2002 to 2016) and the 34-year period that follows the interim surplus criteria (years 2017 to 2050), respectively. These graphs best illustrate the frequency that different amounts of annual Arizona water deliveries occur over these time frames. Table 3.4-1 provides a summary of the comparison for these two periods.

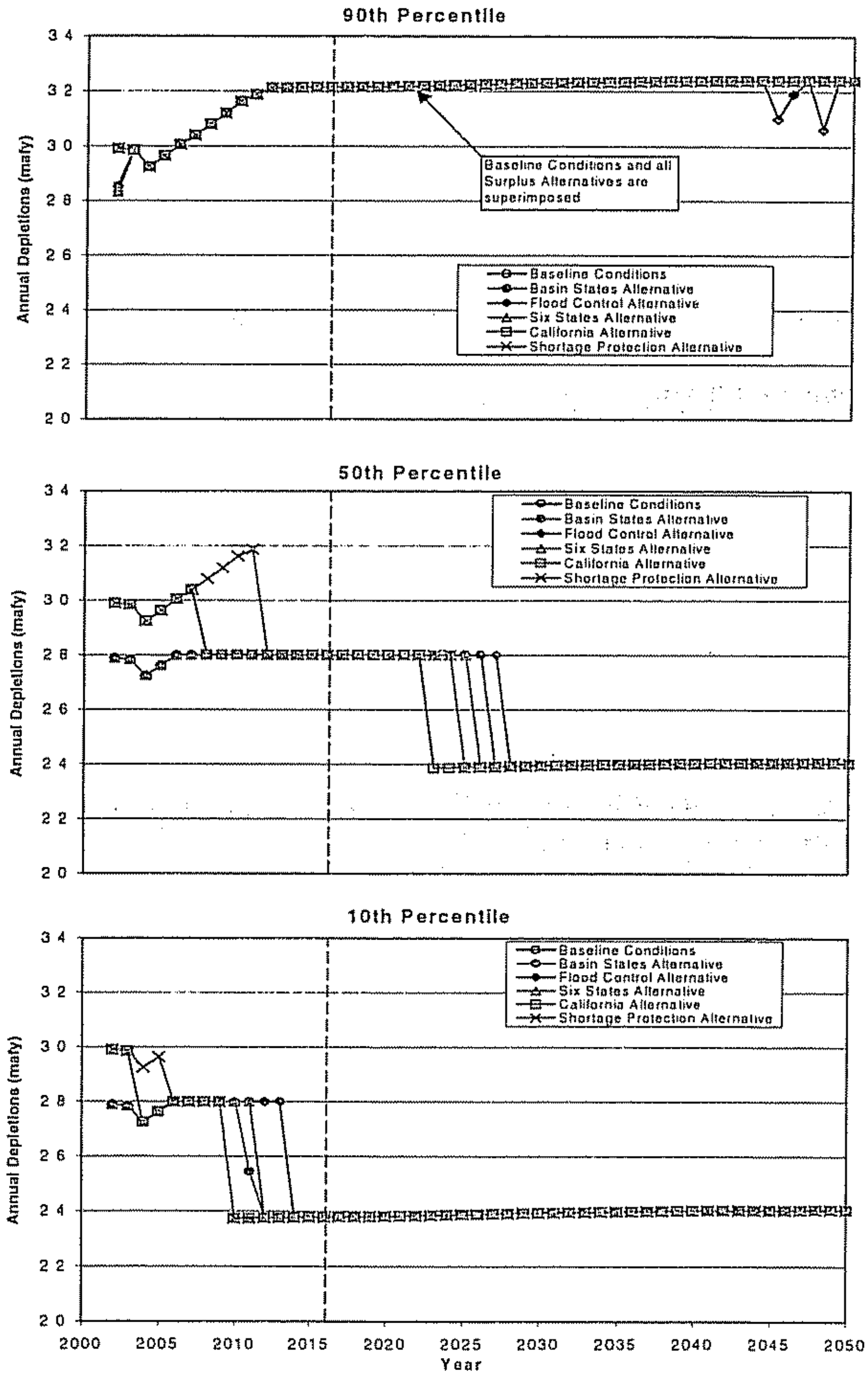
Table 3.4-1
Summary of Arizona Modeled Annual Depletions
Comparison of Surplus Alternatives to Baseline Conditions

Alternative/Conditions	Years 2002 to 2016			Years 2017 to 2050		
	Normal*	Surplus	Shortage	Normal*	Surplus	Shortage
Baseline Conditions	> 96%	29%	< 4%	50%	21%	50%
Basin States	> 92%	25%	< 8%	> 46%	> 21%	< 54%
Flood Control	>96%	27%	< 4%	50%	20%	50%
Six States	> 93%	25%	< 7%	> 47%	21%	< 53%
California	> 86%	55%	< 14%	> 44%	20%	< 56%
Shortage Protection	> 88%	68%	< 12%	> 45%	20%	< 55%

*The values under normal represent the total percentage of time that depletions would be at or above the normal depletion conditions.

The percentage values presented under the column heading labeled "Normal" in Table 3.4-1 represent the total percentage of time that depletions under the noted conditions would be at or above the normal depletion schedule amount. The values presented under the column labeled "Surplus" represent the total percentage of time that depletions under the noted conditions exceed the normal depletion schedule amount. The values presented under the column labeled "Shortage" represent the total percentage of time that depletions under the noted conditions would be below the normal depletion schedule amount.

Figure 3.4-8
Arizona Modeled Annual Depletions
Comparison of Surplus Alternatives to Baseline Conditions
90th, 50th and 10th Percentile Values



3.4.4.2 STATE OF CALIFORNIA

This section presents the simulated water deliveries to California under the baseline conditions and surplus alternatives. The analysis of California's water supply concentrated on total California water depletions. The underlying assumptions for California's depletions under the baseline conditions include: 1) California's normal annual depletion is 4.4 maf; 2) intrastate water transfers are included in the baseline conditions and all alternatives; and 3) surplus deliveries are made during flood control operations and under 70R criteria. The underlying assumption for California's depletions are that several transfers and exchanges will be carried out over a number of years. The transfers and exchanges proposed under California's Colorado River Water Use Plan will result in water transfers between MWD and the agricultural agencies, in particular IID and CVWD. The normal schedules for MWD, IID and CVWD with and without transfers as provided by California are tabulated in Attachment H.

3.4.4.2.1 Baseline Conditions

The water deliveries to California are projected to fluctuate throughout the 50-year period of analysis reflecting variations in hydrologic conditions. The 90th, 50th and 10th percentile rankings of modeled water deliveries to California under the baseline conditions are presented in Figure 3.4-9.

The 90th percentile line generally coincides with California's depletion schedule during full surplus water supply conditions. As indicated by this 90th percentile line, the probability that the baseline conditions would provide California's full surplus depletion amount is at least 10 percent throughout the 50-year period of analysis.

From 2002 through 2050, under baseline conditions, the 50th percentile line for California coincides with its normal depletion schedule.

Annual water deliveries to California never fall below the apportionment of 4.4 maf available for use in California during a normal year. Therefore, no Level 2 shortage condition deliveries to California were observed.

Figure 3.4-9
California Modeled Annual Depletions Under Baseline Conditions
90th, 50th and 10th Percentile Values

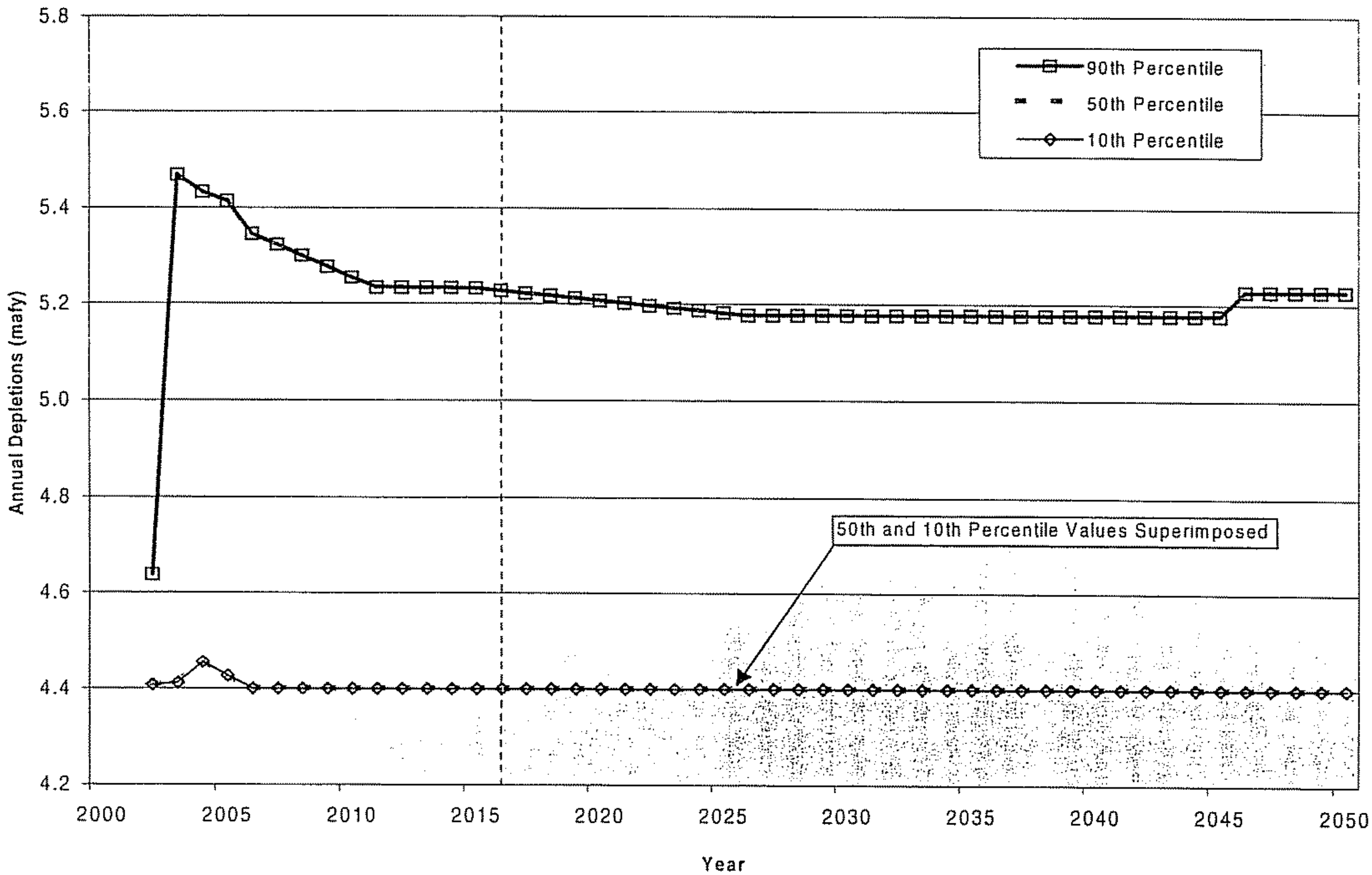


Figure 3.4-10 provides a comparison of the cumulative distribution of California's depletions under the surplus alternatives to those of the baseline conditions during the interim surplus criteria period (years 2002 to 2016). These graphs are best used to represent the frequency that different magnitude annual water deliveries to California occur in the respective period. The results presented in Figure 3.4-10 indicate a 100 percent probability that California's depletions would meet its normal depletion schedule during this period under the baseline conditions. The probability that California would receive surplus condition deliveries (any amount greater than 4.4 mafy) during this period under baseline conditions was approximately 47 percent. The maximum surplus condition depletions observed under the baseline conditions were 5.468 maf during this period.

Figure 3.4-11 provides a comparison of the cumulative distribution of the water deliveries to California under the surplus alternatives to those of the baseline conditions for the 34-year period (years 2017 to 2050) that follows the interim surplus criteria period. The results presented in Figure 3.4-11 indicate a 100 percent probability that water deliveries to California would meet its normal depletion schedule during this period under the baseline conditions. The probability that California would receive surplus condition deliveries during this same period under the baseline conditions was approximately 21 percent. The maximum surplus condition depletions under the baseline conditions were 5.227 maf during this period. During this period, California did not receive shortage condition deliveries.

Figure 3.4-10
California Modeled Depletions
Comparison of Surplus Alternatives to Baseline Conditions
Years 2002 to 2016

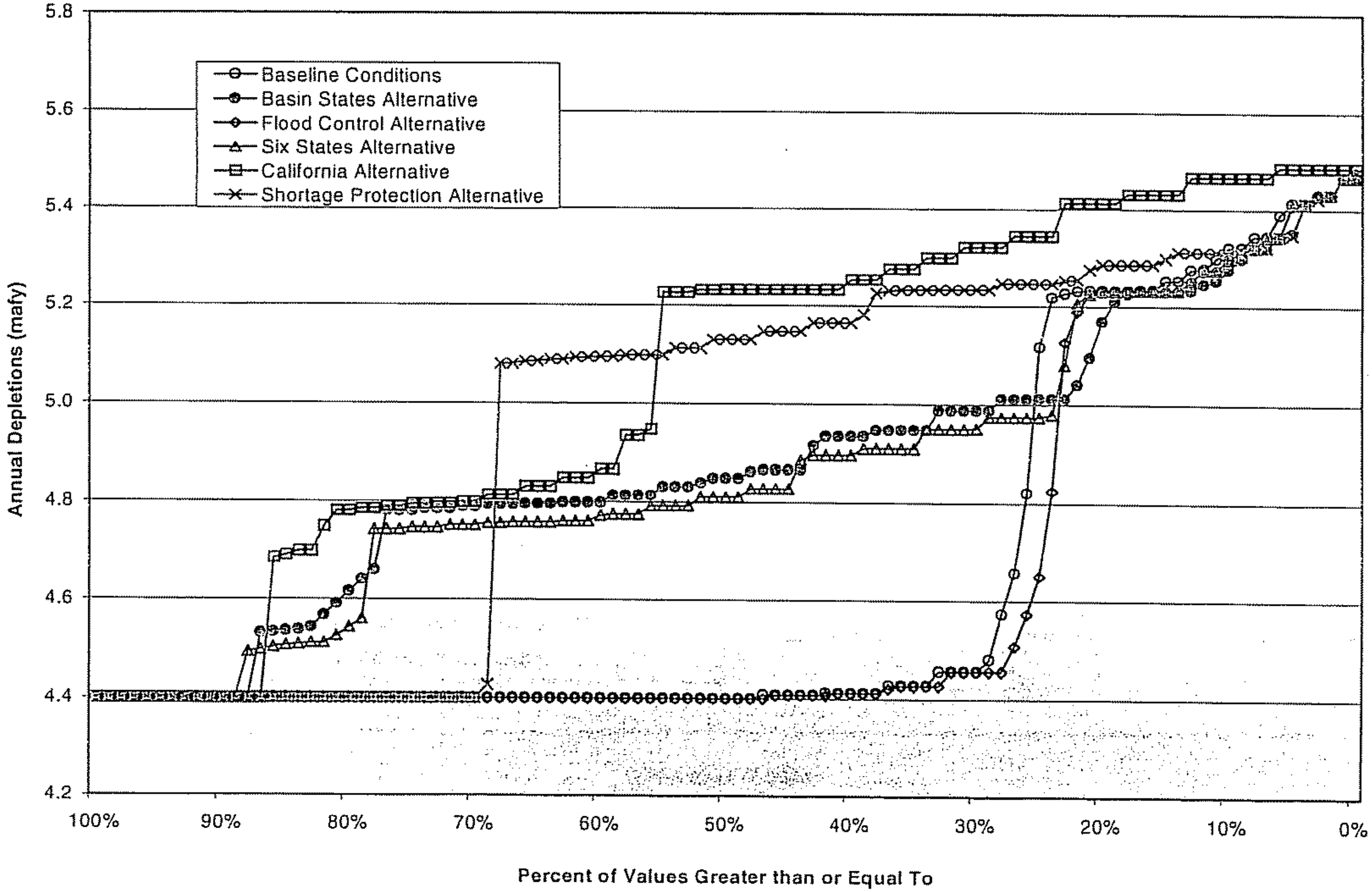
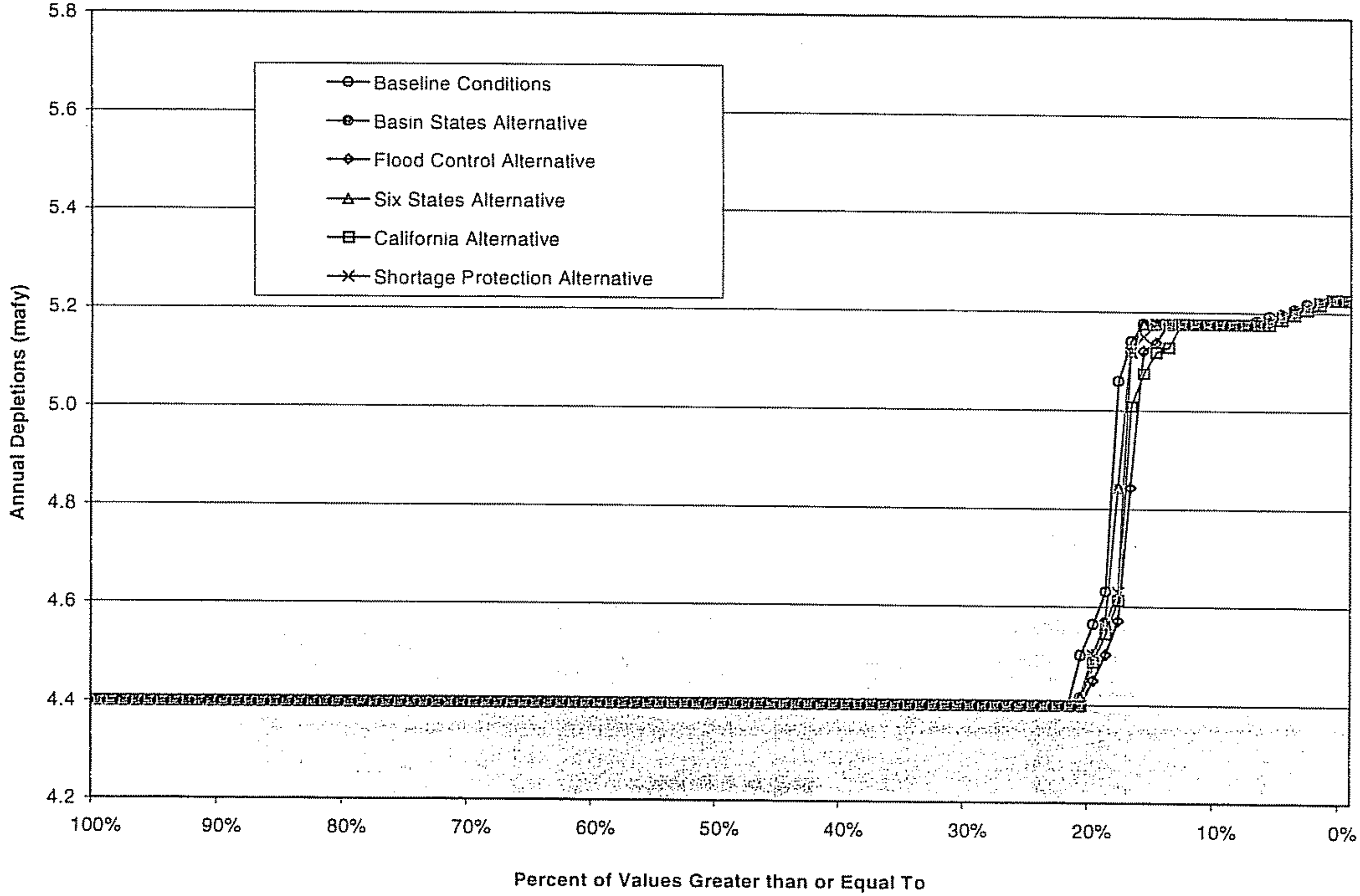


Figure 3.4-11
California Modeled Depletions
Comparison of Surplus Alternatives to Baseline Conditions
Years 2017 to 2050

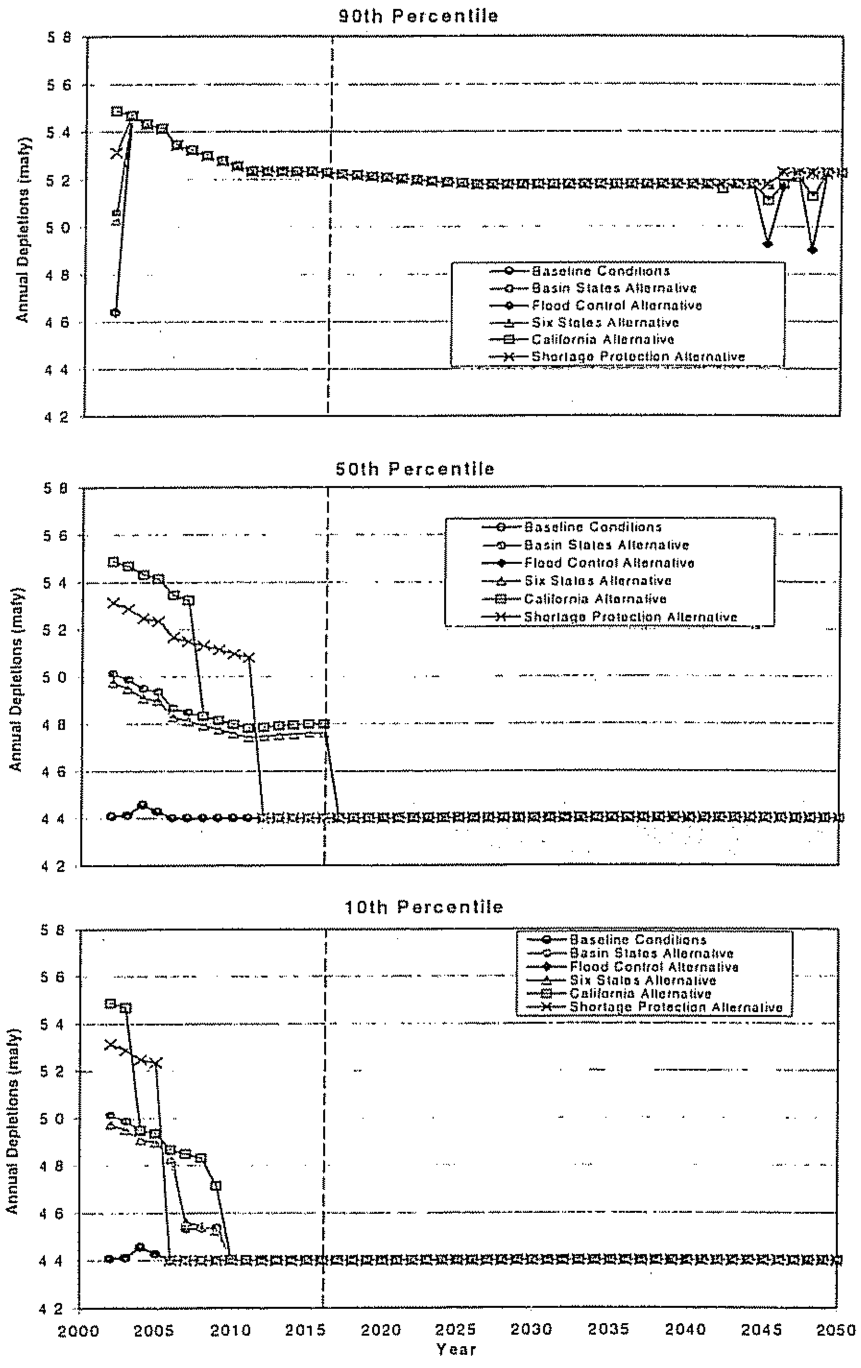


3.4.4.2.2 Comparison of Surplus Alternatives to Baseline Conditions

Figure 3.4-12 provides a comparison of the 90th, 50th and 10th percentile values for California's depletions under the surplus alternatives to those of the baseline conditions

As noted in Figure 3.4-12, there is little difference in the 90th percentile values resulting from the surplus alternatives to those of the baseline conditions. The exceptions to this are in year one and years 2045 to 2050 where the 90th percentile values are less than the full surplus amounts and indicating the occurrence of frequent limited surplus conditions. The 90th percentile lines generally coincide with California's surplus depletion schedule.

Figure 3.4-12
California Modeled Annual Depletions
Comparison of Surplus Alternatives to Baseline Conditions
90th, 50th and 10th Percentile Values



The 50th percentile lines for the Basin States, Six States, California, and Shortage Protection alternatives are above California's normal depletion schedule during all or most of the 15-year interim surplus criteria, indicating a high probability of surplus conditions under these alternatives. The 50th percentile lines for the baseline conditions and Flood Control Alternative generally coincide with California's normal depletion schedule throughout the 50-year period of analysis. Beyond 2016, the 50th percentile lines for all of the surplus alternatives also coincide with California's normal depletion schedule.

The 10th percentile lines for the baseline conditions and the Flood Control Alternative coincide with California's normal depletion schedule throughout the 50-year period of analysis. The 10th percentile values for the Basin States, Six States, California, and Shortage Protective alternatives are essentially above the normal depletion schedule through year 2009 (2005 for the Shortage Protection Alternative). The 10th percentile lines for the baseline conditions and the surplus alternatives converge after 2009.

Figures 3.4-10 and 3.4-11 presented comparisons of the cumulative distribution of California's depletions under the surplus alternatives to those of the baseline conditions during the interim surplus criteria period (years 2002 to 2016) and the 34-year period that would follow the interim surplus criteria (years 2017 to 2050), respectively. Table 3.4-2 provides a tabular summary and comparison for these two periods.

Table 3.4-2
Summary of California Modeled Annual Depletions
Comparison of Surplus Alternatives to Baseline Conditions

Alternative/Conditions	Years 2002 to 2016			Years 2017 to 2050		
	Normal*	Surplus	Shortage	Normal*	Surplus	Shortage
Baseline Conditions	100%	47%	0%	100%	21%	0%
Basin States	100%	87%	0%	100%	21%	0%
Flood Control	100%	46%	0%	100%	20%	0%
Six States	100%	69%	0%	100%	21%	0%
California	100%	86%	0%	100%	20%	0%
Shortage Protection	100%	69%	0%	100%	20%	0%

The percentage values presented under the column heading labeled "Normal" in Table 3.4-2 represent the total percentage of time that depletions under the noted conditions would be at or above the normal depletion schedule amount. The values presented under the column labeled "Surplus" represent the total percentage of time that depletions under the noted conditions exceed the normal depletion schedule amount. The values presented under the column labeled "Shortage" represent the total percentage of time that depletions under the noted conditions would be below the normal depletion schedule amount.

3.4.4.3 STATE OF NEVADA

This section presents the simulated water deliveries to Nevada under the baseline conditions and surplus alternatives. The analysis of Nevada's water supply concentrated on total Nevada water depletions.

3.4.4.3.1 Baseline Conditions

The water deliveries to Nevada are projected to fluctuate throughout the 50-year period of analysis reflecting variations in hydrologic conditions. The 90th, 50th and 10th percentile ranking of modeled water deliveries to Nevada under the baseline conditions is presented in Figure 3.4-13. The 90th percentile line generally coincides with Nevada's depletion schedule during full surplus water supply conditions. As indicated by this 90th percentile line, the probability that the baseline conditions would provide Nevada's full surplus depletion amount is at least 10 percent throughout the 50-year period of analysis.

The 50th percentile line generally coincides with Nevada's normal depletion schedule under baseline conditions through year 2026. Thereafter, the 50th percentile line drops to and coincides with Nevada's Level 1 shortage depletion schedule.

As noted in Section 3.4.3, the SNWA and CAP essentially take all the reductions in water deliveries during shortage conditions (for modeling purposes). The model sets the SNWA's shortage condition delivery reductions to four percent of the total shortage condition delivery reduction amount when the Lake Mead water level is between elevation 1000 feet msl and the assumed shortage protection line as discussed in Section 3.3.3.4. This modeling assumption kept Nevada' annual delivery above 280 kaf until further cuts to the SNWA and CAP were necessary to maintain the Lake Mead water level above the 1000 feet msl elevation, a level 2 shortage condition. Under the baseline conditions, deliveries to Nevada below 280 kaf occurred less than four percent of the time during the 15-year interim surplus criteria period.

Under the baseline conditions, the 10th percentile line remains at or above Nevada's normal depletion schedule until 2013. Beyond 2013, the 10th percentile line drops to Nevada's Level 1 shortage condition depletion schedule.

Figure 3.4-13
Nevada Modeled Annual Depletions Under Baseline Conditions
90th, 50th and 10th Percentile Values

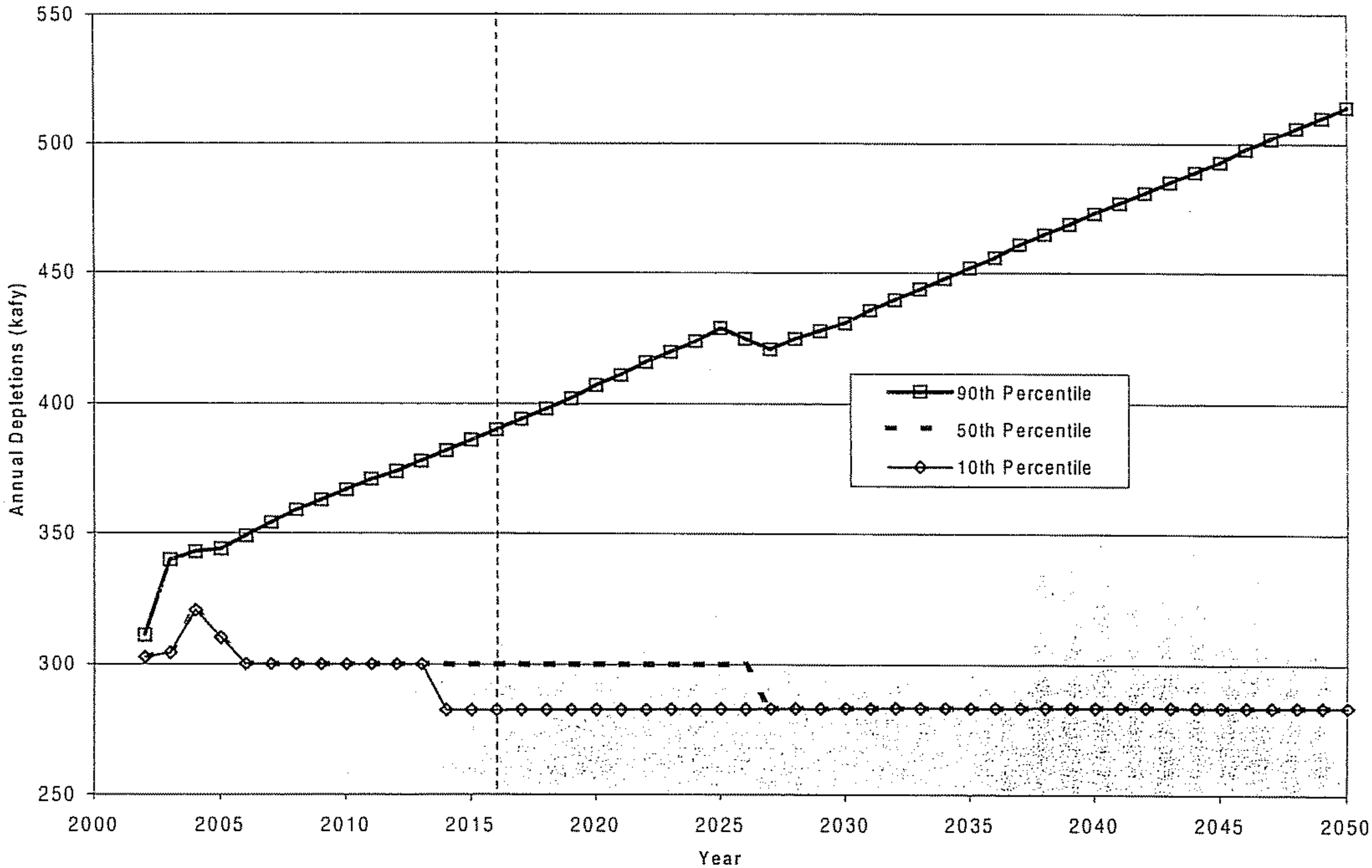


Figure 3.4-14 provides a comparison of the cumulative distribution of Nevada's depletions under the surplus alternatives to those of the baseline conditions during the interim surplus criteria period (years 2002 to 2016). This graph is best used to represent the frequency that different magnitude water deliveries to Nevada occurred during the 15-year interim surplus criteria period. The results presented in Figure 3.4-14 indicate a 96 percent probability that water deliveries to Nevada would meet or exceed its normal depletion schedule during this period under the baseline conditions. The probability that Nevada would receive surplus condition deliveries under the baseline conditions during this period was approximately 47 percent. The maximum surplus condition depletions under the baseline conditions were 390 kaf during this period. The probability that Nevada would receive shortage condition deliveries under baseline conditions was less than four percent. The minimum shortage condition depletion was 282.3 kaf.

Figure 3.4-14
Nevada Modeled Depletions
Comparison of Surplus Alternatives to Baseline Conditions
Years 2002 to 2016

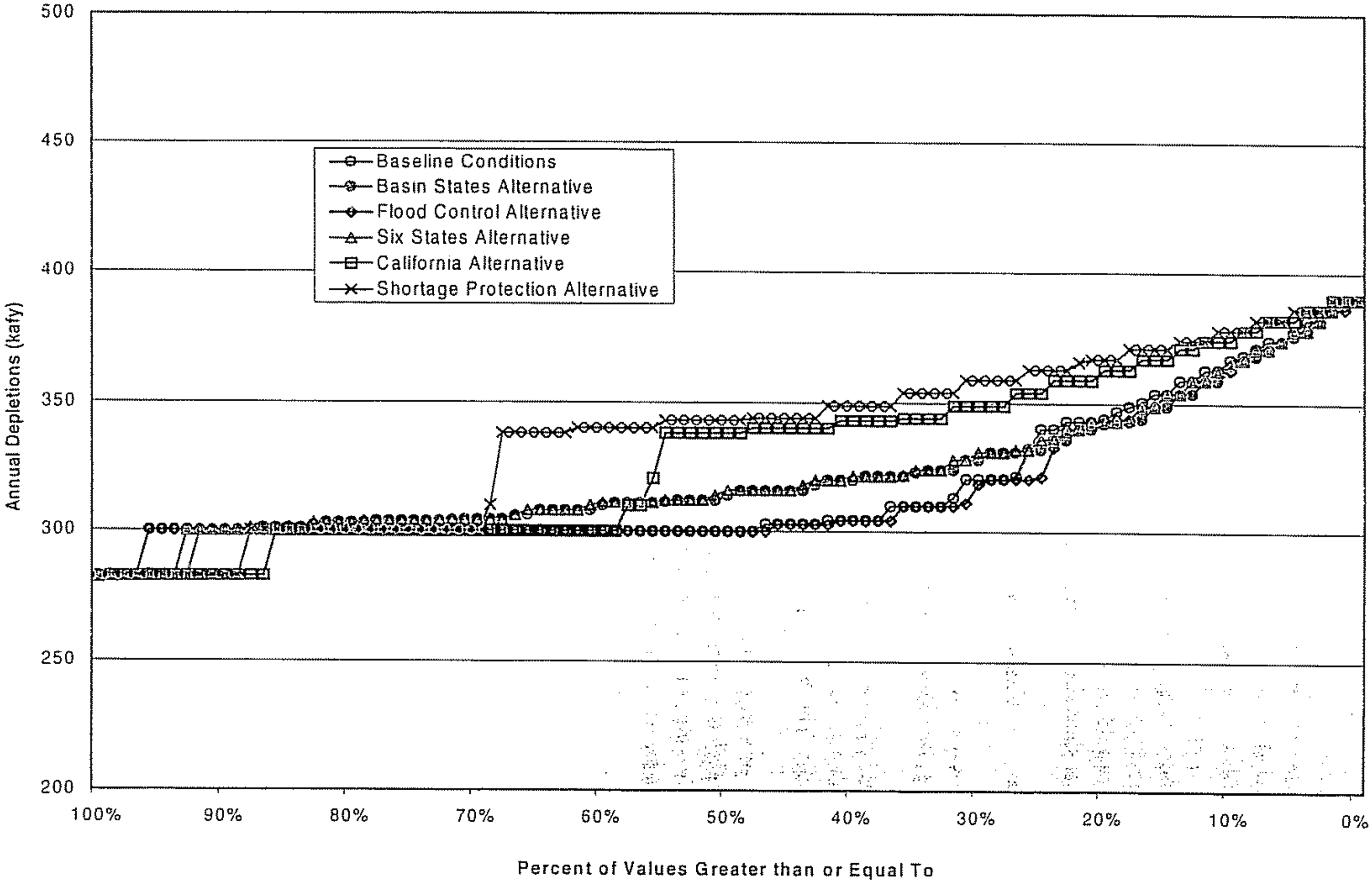


Figure 3.4-15 provides a comparison of the cumulative distribution of the water deliveries to Nevada under the surplus alternatives to those of the baseline conditions for the 34-year period (years 2017 to 2050) that would follow the interim surplus criteria period. The results presented in Figure 3.4-15 indicate a 50 percent probability that water deliveries to Nevada would meet or exceed its normal depletion schedule during this period under the baseline conditions. The probability that Nevada would receive surplus condition deliveries during this same period under the baseline conditions was approximately 21 percent. The maximum surplus condition depletions under the baseline conditions were 514 kaf during this period. The probability that Nevada would receive shortage condition deliveries was approximately 50 percent. The minimum shortage condition depletion during this period was 249.8 kaf.

3.4.4.3.2 Comparison of Surplus Alternatives to Baseline Conditions

Figure 3.4-16 provides a comparison of the 90th, 50th and 10th percentile values for Nevada's depletions under the baseline conditions to those of the surplus alternatives.

As noted in Figure 3.4-16, there is little difference in the 90th percentile values generally resulting from the surplus alternatives where compared to those of the baseline conditions. The 90th percentile linescoincide with Nevada's surplus depletion schedule.

The 50th percentile lines for the baseline conditions generally stay at or above Nevada's normal depletion schedule through year 2022. From 2022 through 2027, the 10th percentile values for the baseline conditions and surplus alternatives drop to and remain at a level equal to Nevada's Level 1 shortage depletion schedule.

Figure 3.4-15
Nevada Modeled Depletions
Comparison of Surplus Alternatives to Baseline Conditions
Years 2017 to 2050

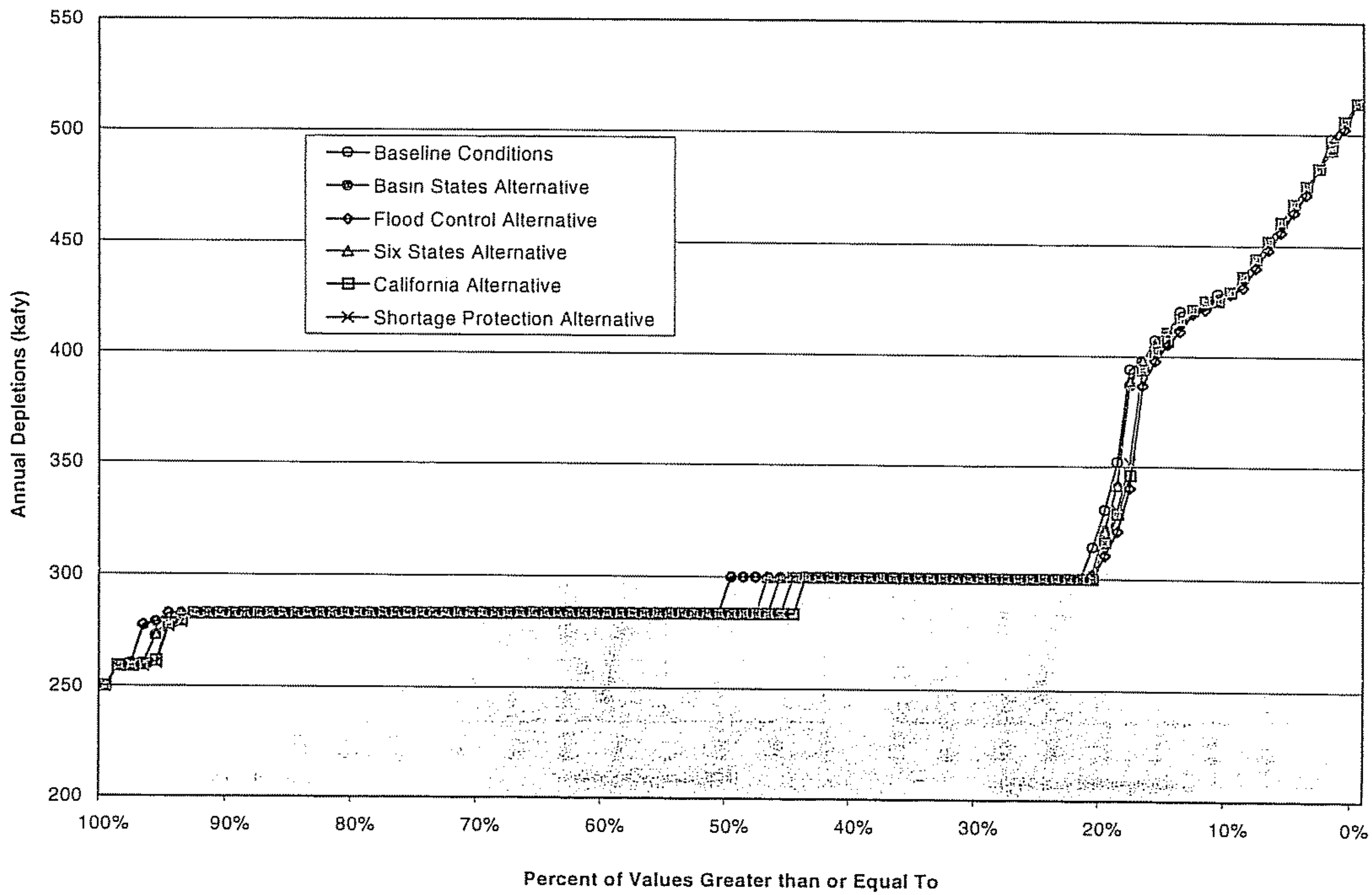
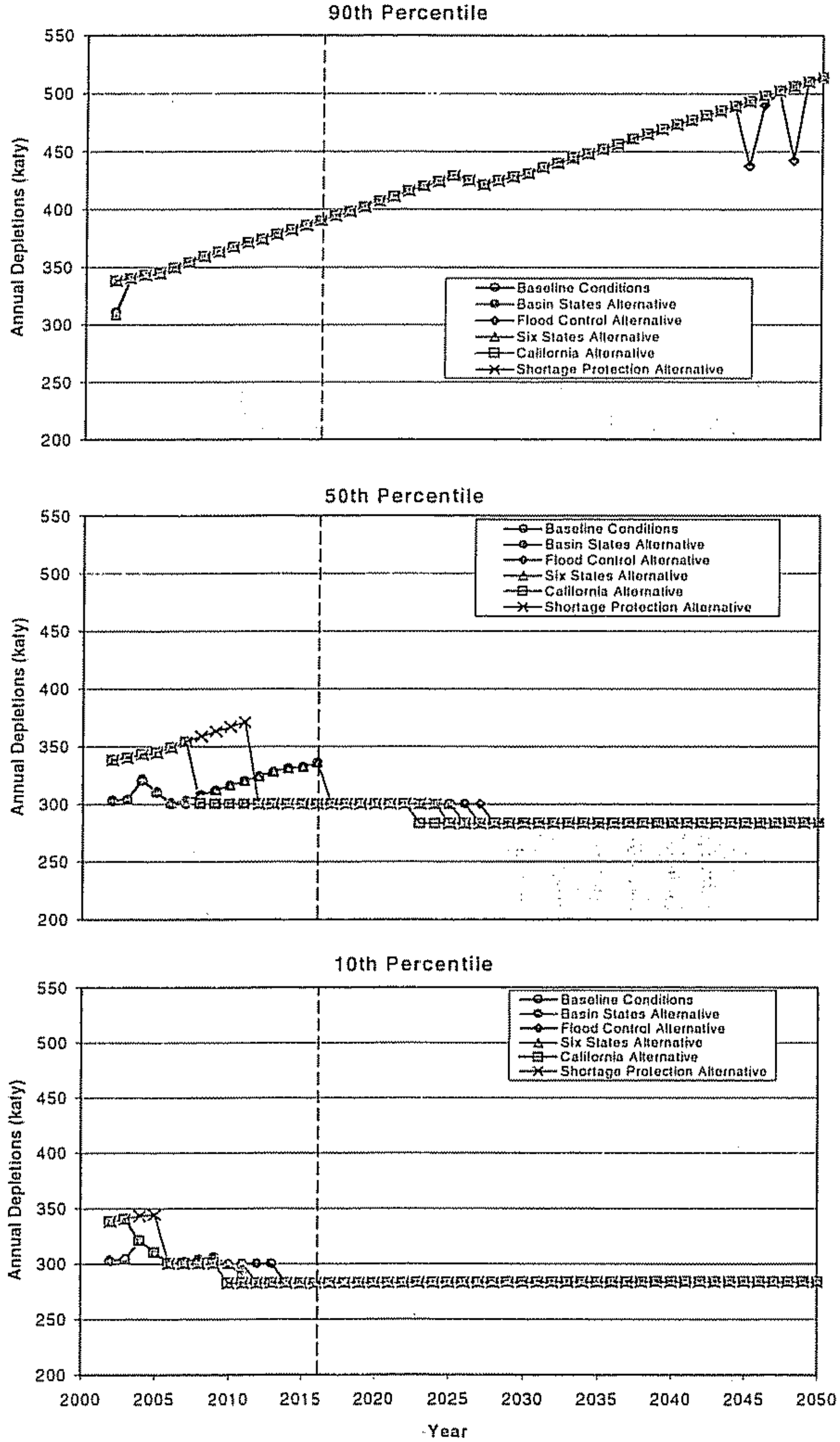


Figure 3.4-16
Nevada Modeled Annual Depletions
Comparison of Surplus Alternatives to Baseline Conditions
90th, 50th and 10th Percentile Values



The 10^{th} percentile lines for the baseline conditions and surplus alternatives generally stay at or above Nevada's Level 1 shortage depletion schedule through year 2009. Between years 2009 through 2013, the 10^{th} percentile lines for the baseline conditions and surplus alternatives drop to and remain at a level equal to Nevada's Level 1 shortage depletion schedule.

Figures 3.4-14 and 3.4-15 presented comparisons of the cumulative distribution of Nevada's depletions under the surplus alternatives to those of the baseline conditions during the interim surplus criteria period (years 2002 to 2016) and the 34-year period that would follow the interim surplus criteria (years 2017 to 2050), respectively. These graphs represent the frequency that different magnitude annual deliveries to Nevada occurred under each respective period. Table 3.4-3 provides a tabular summary of the comparison for these two periods.

Table 3.4-3
Summary of Nevada Modeled Annual Depletions
Comparison of Surplus Alternatives to Baseline Conditions

Alternative/Conditions	Years 2002 to 2016			Years 2017 to 2050		
	Normal	Surplus	Shortage	Normal	Surplus	Shortage
Baseline Conditions	> 96%	47%	< 4%	50%	21%	50%
Basin States	> 92%	87%	< 8%	> 46%	21%	< 54%
Flood Control	> 96%	91%	< 4%	50%	20%	50%
Six States	> 93%	88%	< 7%	> 47%	27%	< 53%
California	> 86%	58%	< 14%	> 44%	21%	< 56%
Shortage Protection	> 88%	11%	< 12%	> 46%	20%	< 54%

*The values under normal represent the total percentage of time that depletions would be at or above the normal depletion conditions

The percentage values presented under the column heading labeled "Normal" in Table 3.4-3 represent the total percentage of time that depletions under the noted conditions would be at or above the normal depletion schedule amount. The values presented under the column labeled "Surplus" represent the total percentage of time that depletions under the noted conditions exceed the normal depletion schedule amount. The values presented under the column labeled "Shortage" represent the total percentage of time that depletions under the noted conditions would be below the normal depletion schedule amount.

3.4.4.4 UPPER BASIN STATES

There are no specific criteria in the *Law of the River* for surplus or shortage condition water deliveries to users within the Upper Basin states. The normal depletion schedule of the Upper Basin states would be met under most water supply conditions. The exceptions are potential reductions to certain Upper Basin users whose diversions are located upstream of Lake Powell. For these users, the potential reductions would be attributed to dry hydrologic conditions and inadequate regulating reservoir storage capacity upstream of their diversions.

The proposed interim surplus criteria were determined to have no effect on water deliveries to the Upper Basin states, including the Upper Basin Tribes. Therefore, detailed analyses were not necessary for the Upper Basin states' water supply.

3.4.4.5 MEXICO

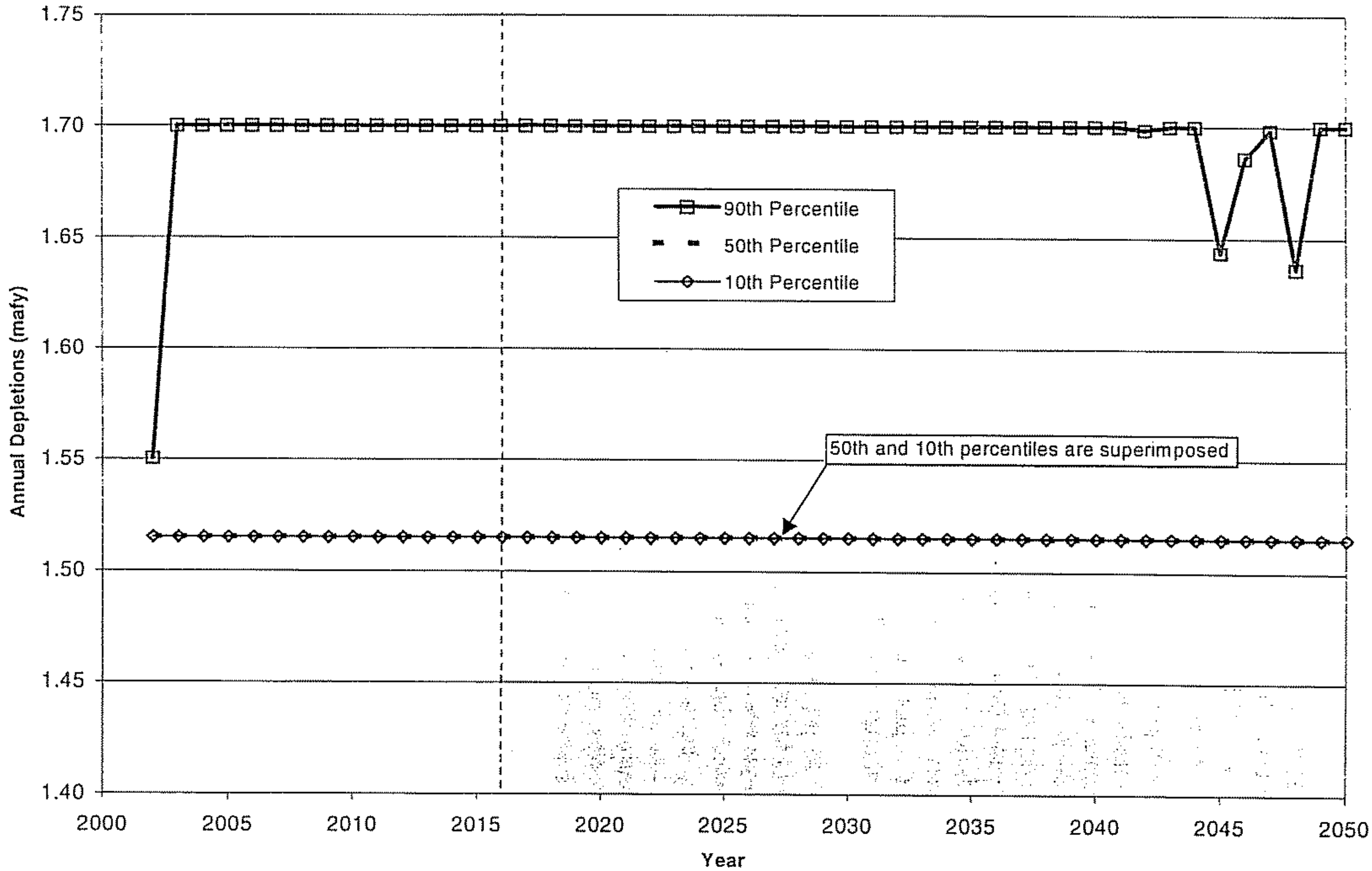
This section presents the simulated water deliveries to Mexico under the baseline conditions and surplus alternatives. As discussed previously, Mexico's normal depletion schedule is modeled as 1.515 maf. An additional 15,000 af is included to account for typical scheduling errors and water that is ordered by the Lower Basin users but that is not diverted. Surplus deliveries to Mexico of up to 200 kaf are delivered under baseline conditions and the surplus alternatives only when Lake Mead makes flood control releases. Shortage deliveries to Mexico would only occur if the CAP were cut to zero and further cuts to MWD and Mexico were necessary to keep the Lake Mead water elevation above 1000 feet msl. This condition was not observed under the baseline conditions or the surplus alternatives.

3.4.4.5.1 Baseline Conditions

The water deliveries to Mexico are projected to be at or above Mexico's normal delivery schedule throughout the 50-year period of analysis. The 90th, 50th and 10th percentile ranking of modeled water deliveries to Mexico under the baseline conditions are presented in Figure 3.4-17.

The 90th percentile line generally coincides with Mexico's depletion schedule during surplus water supply conditions throughout the 50-year period of analysis. The exception to these are the years between 2045 to 2050 when 90th percentile values drop to levels slightly below the full surplus schedule amounts. As indicated by this 90th percentile line, the probability that the baseline conditions would provide Mexico's surplus depletion amount is at least 10 percent throughout the 50-year period of analysis.

Figure 3.4-17
Mexico Modeled Annual Depletions Under Baseline Conditions
90^{th}, 50^{th} and 10^{th} Percentile Values



Under baseline conditions, the 50th and 10th percentile lines coincide with Mexico's normal depletion schedule. Again, it is noted that the depletion amount depicted by both the 50th and 10th percentile lines is equal to 1.515 maf. The 15,000 af above the 1.5 maf Mexico apportionment was added to the model to account for typical scheduling errors and water that is ordered by the Lower Basin users but that is not diverted. Also, it should be noted that the modeled water deliveries to Mexico never dropped below Mexico's normal depletion schedule

Figure 3.4-18 provides a comparison of the cumulative distribution of Mexico's depletions under the surplus alternatives to those of the baseline conditions during the interim surplus criteria period (years 2002 to 2016) Again, this type of graph is used to represent the frequency that annual deliveries of different magnitudes occur in the respective period. The results presented in Figure 3.4-18 indicate a 100 percent probability that Mexico's depletions would meet or exceed its normal depletion schedule during this period under the baseline conditions. The probability that Mexico would receive surplus condition deliveries during this period was approximately 26 percent under baseline conditions. The maximum surplus condition depletion under the baseline conditions was 1.7 maf during this period.

Figure 3.4-19 provides a comparison of the cumulative distribution of the water deliveries to Mexico under the surplus alternatives to those of the baseline conditions for the 34-year period (years 2017 to 2050) that would follow the interim surplus criteria period. The results presented in Figure 3.4-19 also indicate a 100 percent probability that water deliveries to Mexico would meet its normal depletion schedule during this period under the baseline conditions. The probability that Mexico would receive surplus condition deliveries during this same period under the baseline conditions was approximately 19 percent. The maximum surplus condition depletion under the baseline conditions was also 1.7 maf during this period.

Figure 3.4-18
Mexico Modeled Depletions
Comparison of Surplus Alternatives to Baseline Conditions
Years 2002 to 2016

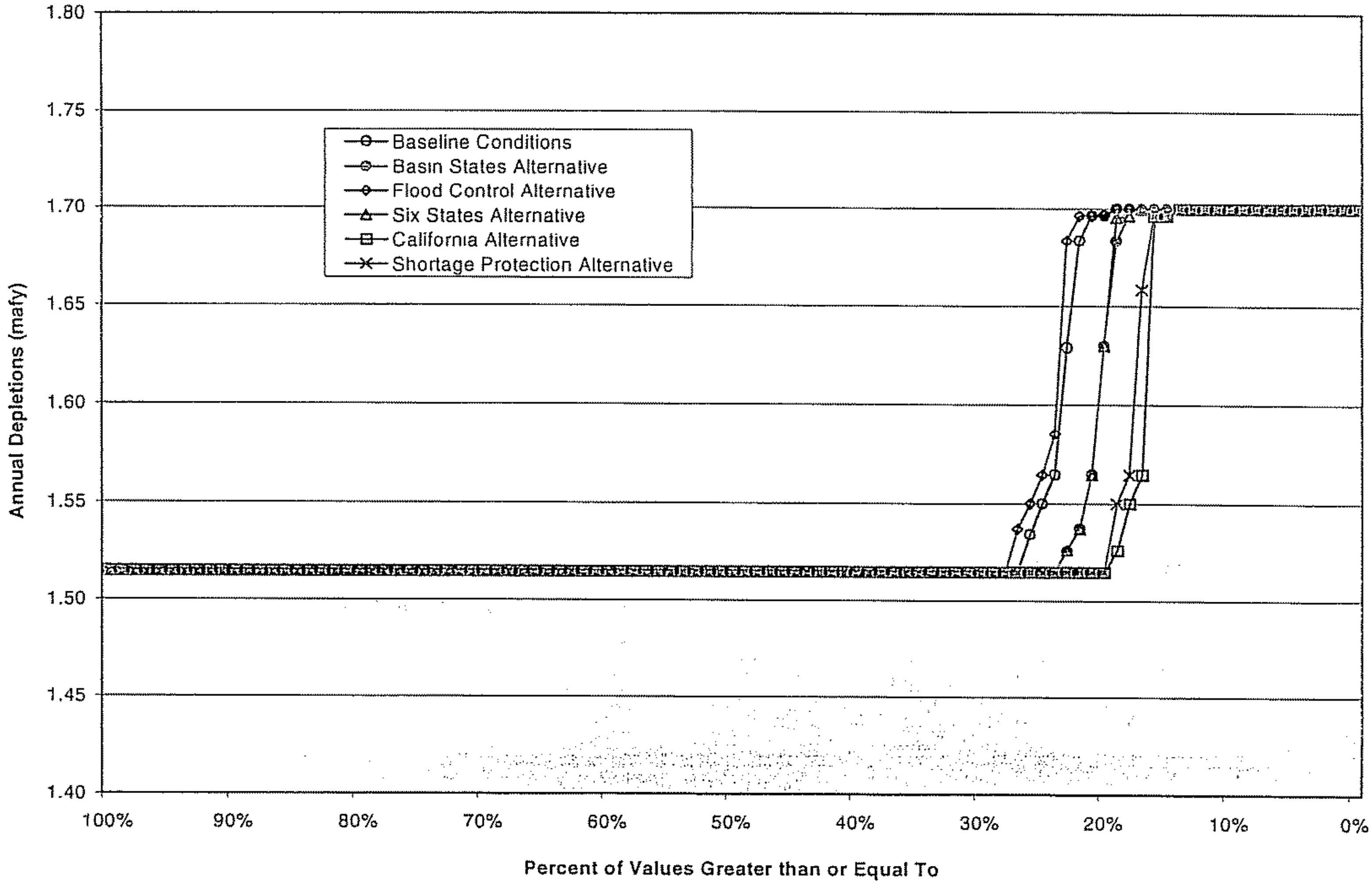
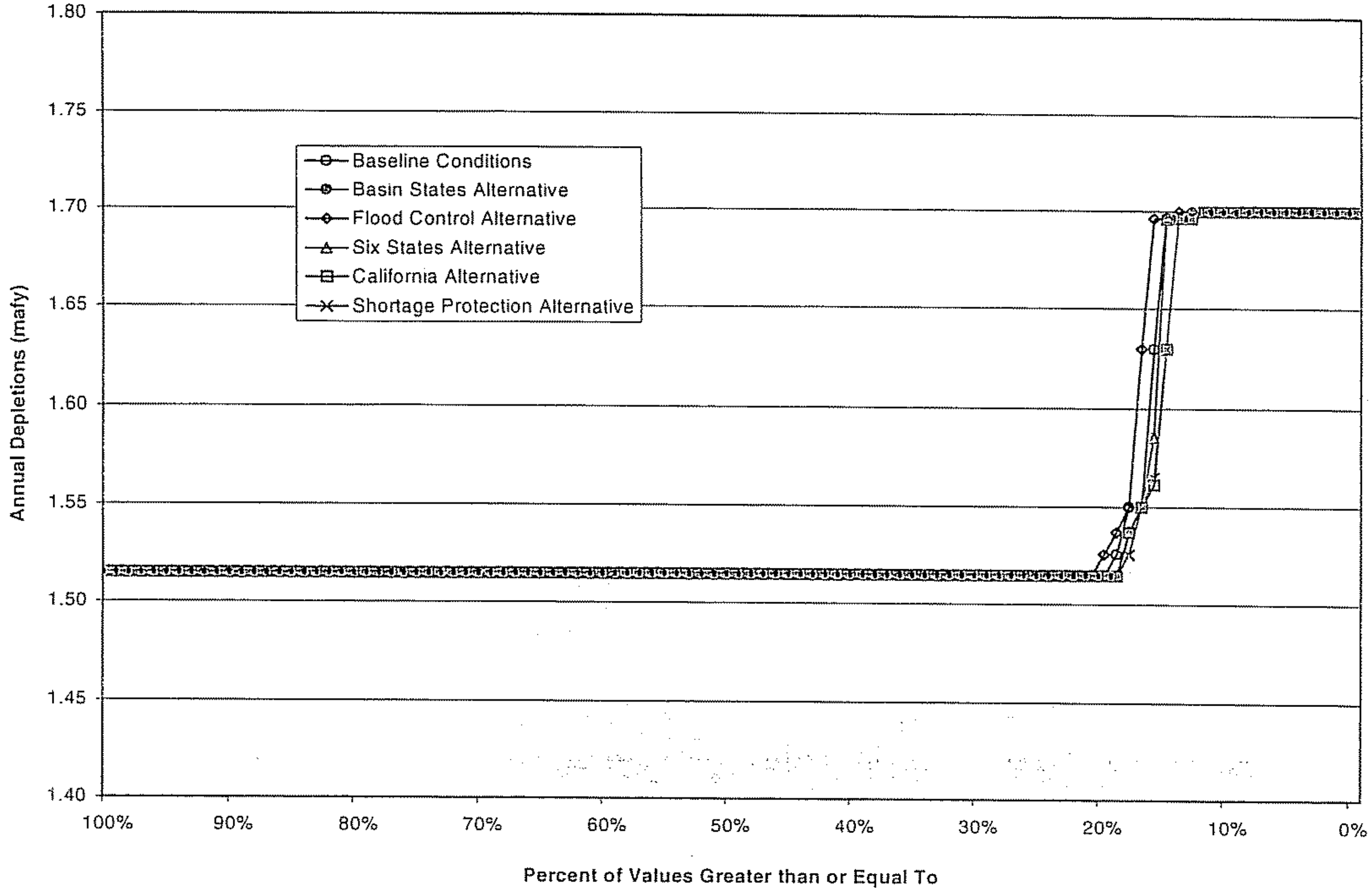


Figure 3.4-19
Mexico Modeled Depletions
Comparison of Surplus Alternatives to Baseline Conditions
Years 2017 to 2050



3.4.4.5.2 Comparison of Surplus Alternatives to Baseline Conditions

Figure 3.4-20 provides a comparison of the 90th, 50th and 10th percentile values for Mexico's depletions under the surplus alternatives to those of the baseline conditions.

As noted in Figure 3.4-20, there is essentially no difference in the 90th percentile lines resulting from the surplus alternatives when compared to those of the baseline conditions. The 90th percentile lines generally coincide with Mexico's surplus depletion schedule.

The 50th and percentile lines for all the surplus alternatives and the baseline conditions coincide with Mexico's normal depletion schedule. Again, water deliveries to Mexico were not observed to fall below Mexico's 1.5 maf apportionment.

Figures 3.4-18 and 3.4-19 presented comparisons of the cumulative distribution of Mexico's depletions under the surplus alternatives to those of the baseline conditions during the interim surplus criteria period for years 2002 to 2016 and the 34-year period that follows the interim surplus criteria (years 2017 to 2050), respectively. Table 3.4-4 provides a tabular summary of the comparison for these two periods.

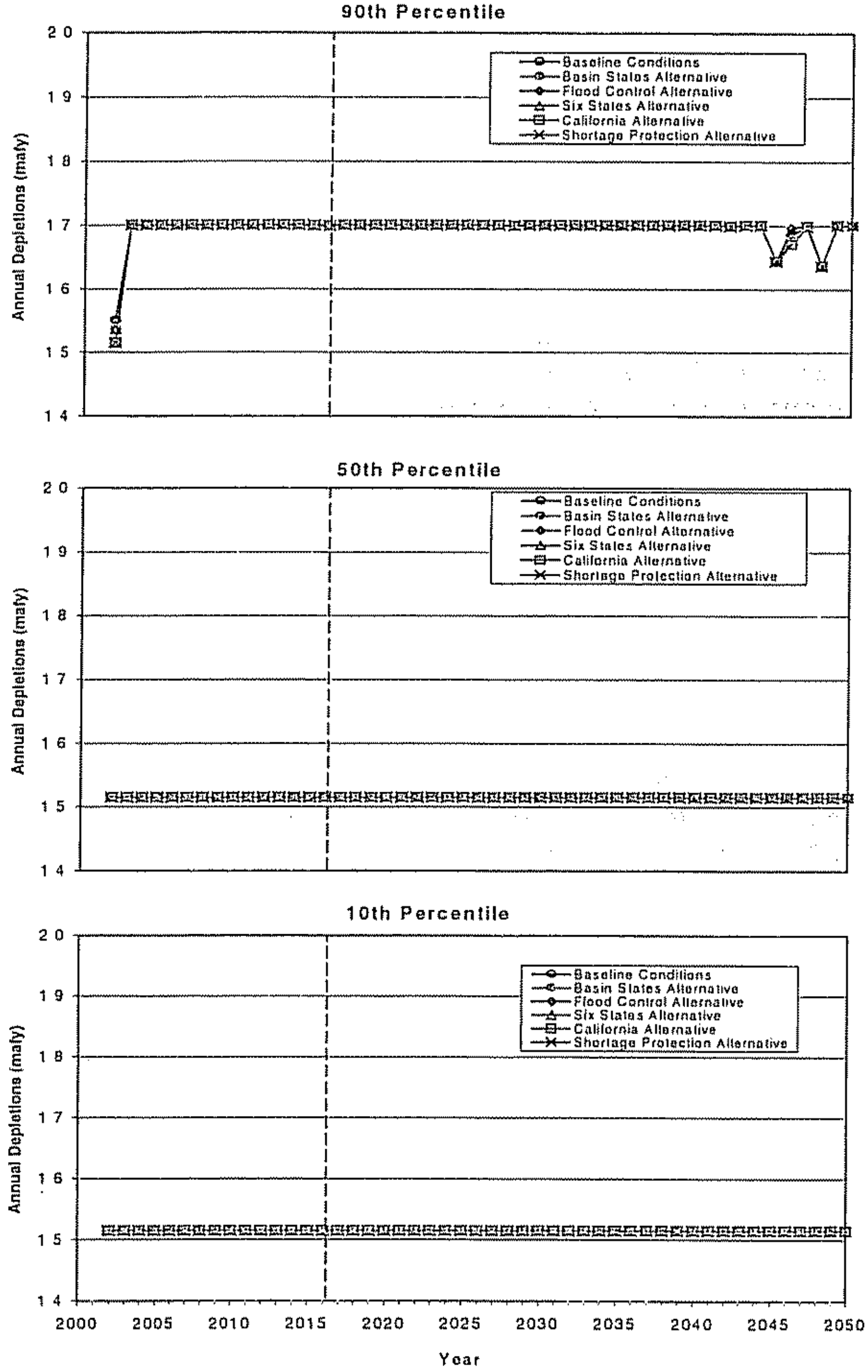
Table 3.4-4
Summary of Mexico Modeled Annual Depletions
Comparison of Surplus Alternatives to Baseline Conditions

Alternative/Conditions	Years 2002 to 2016			Years 2017 to 2050		
	Normal*	Surplus	Shortage	Normal*	Surplus	Shortage
Baseline Conditions	100%	26%	0%	100%	19%	0%
Basin States	100%	23%	0%	100%	18%	0%
Flood Control	100%	27%	0%	100%	20%	0%
Six States	100%	23%	0%	100%	18%	0%
California	100%	19%	0%	100%	18%	0%
Shortage Protection	100%	19%	0%	100%	18%	0%

*The values under normal represent the total percentage of time that depletions would be at or above the normal depletion conditions.

The percentage values presented under the column heading labeled "Normal" in Table 3.4-4 represent the total percentage of time that depletions under the noted conditions would be at or above the normal depletion schedule amount. The values presented under the column labeled "Surplus" represent the total percentage of time that depletions under the noted conditions exceed the normal depletion schedule amount. The values presented under the column labeled "Shortage" represent the total percentage of time that depletions under the noted conditions would be below the normal depletion schedule amount.

Figure 3.4-20
Mexico Modeled Annual Depletions
Comparison of Surplus Alternatives to Baseline Conditions
90th, 50th and 10th Percentile Values



3.5 WATER QUALITY

3.5.1 INTRODUCTION

This section addresses the salinity of the Colorado River and mainstream reservoirs, and the quality of Lake Mead water available for municipal and industrial purposes. The potential changes in the operation of the Colorado River system downstream from Lake Powell under interim surplus criteria alternatives could temporarily affect the salinity of Colorado River water, which affects municipal and industrial uses in the Lower Basin. In addition, changes in Lake Mead water levels could affect the quality of water arriving at the SNWS pump intakes in the Boulder Basin of Lake Mead, and thereby affect the quality of the water supply for the Las Vegas Valley.

3.5.2 COLORADO RIVER SALINITY

This section discusses potential effects that could result from the implementation of the interim surplus criteria alternatives under consideration. Salinity has long been recognized as one of the major problems of the Colorado River. "Salinity" or "total dissolved solids" (TDS) include all of the soluble constituents dissolved in a river and the two terms are used interchangeably in this document. This section considers potential changes in salinity concentrations from Lake Mead to Imperial Dam. The section also presents a general discussion of the adverse effects of increased salinity concentrations on municipal and industrial systems.

3.5.2.1 METHODOLOGY

Reclamation's model for salinity is used to create salinity reduction targets for the Colorado River Basin Salinity Control Program (SCP). To do this, the model simulates the effects of scheduled water development projects to predict future salinity levels. This data is then used to compute the amount of new salinity control projects required to reduce the river's salinity to meet the standards at some point in the future (2015). The model itself does not include future salinity controls because implementation schedules for future salinity control projects are not fixed and vary considerably. The salinity control standards are purposefully designed to be long-term (nondegradation) goals, rather than exceedence standards used for industry or drinking water.

By definition, the SCP is designed to be flexible enough to adjust for any changes caused by the various alternatives being considered. Therefore, it could be concluded that there would be no change in compliance with the standards caused by selecting any one of the alternatives. However, for the purposes of this analysis, each alternative has been evaluated using fixed (existing) levels of salinity controls to identify the differences between alternatives and the baseline conditions.

General effects of salinity were determined from review of records of historic river flow and salinity data available and economic impacts presented in *Quality of Water Colorado River Basin – Progress Report No. 19*, 1999, U.S. Department of the Interior; *Water Quality Standards for Salinity Colorado River System, 1999 Review*, June 1999, Colorado River Basin Salinity Control Forum and *Salinity Management Study*, Technical Appendices, June 1999, Bookman-Edmonston Engineering, Inc.

The salinity program as set forth in the Forum's 1999 Annual Review enables the numeric criteria to be met through the year 2015. Therefore, it was presumed that the criteria would be maintained through 2015. Although the 1999 Review considers only the period to 2015, it was presumed that future additions to the salinity control program will be sufficient to maintain the criteria through 2050.

3.5.2.2 AFFECTED ENVIRONMENT

3.5.2.2.1 Historical Data

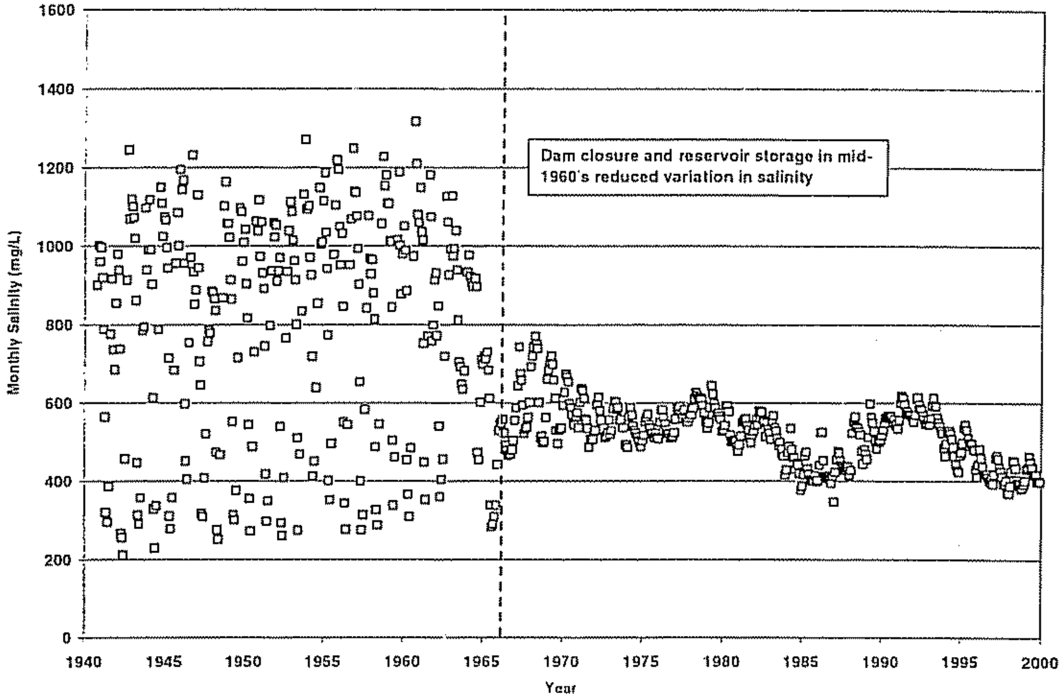
The Colorado River increases in salinity from its headwaters to its mouth, carrying an average salt load of nine million tons annually past Hoover Dam. Approximately half (47 percent) of the salinity concentration is naturally caused and 53 percent of the concentration results from human activities including agricultural runoff, evaporation and municipal and industrial sources (Forum, 1999).

Salinity of the river has fluctuated significantly over the period of record 1941 through 1997. Below Hoover Dam, annual salinity concentrations have ranged from 833 milligrams per liter (mg/l) in 1956 to 517 mg/l in 1986. However, the maximum monthly fluctuation in any year is approximately 50 mg/l. Salinity of the river is influenced by numerous factors including reservoir storage, water resource development (and associated return flows), salinity control, climatic conditions and natural runoff.

The impact of reservoir storage has all but eliminated seasonal fluctuations in salinity. Annual variations in salinity are primarily driven by natural, climatic variations in precipitation and snowmelt runoff. These hydrologic variations cause differences in both flow and salinity.

As shown in Figure 3.5-1, the salinity of the river varied by as much as 1000 mg/l prior to the construction of Glen Canyon Dam in 1961. By the 1980s, that variation was reduced to about 200 mg/l due to the mixing and dampening effect of the large volume of storage in Lake Powell. Figures 3.5-2 and 3.5-3 show the comparison between mainstream flows and salinity. Figure 3.5-2 shows the outflow from Glen Canyon and Imperial Dams. Figure 3.5-3 shows the salinity at Imperial, Hoover and Glen Canyon dams.

Figure 3.5-1
Historical Monthly Salinity Concentrations Below Glen Canyon Dam (1940-1995)



3.5.2.2.2 Regulatory Requirements and Salinity Control Programs

In 1972, the EPA promulgated regulations requiring water quality standards for salinity, numeric criteria and a plan of implementation for salinity control. The Seven Colorado River Basin States, acting through the Forum, adopted numeric criteria for flow-weighted average annual salinity, at three points on the river as shown below:

Below Hoover Dam	723 mg/l
Below Parker Dam	747 mg/l
At Imperial Dam	879 mg/l

Figure 3.5-2
Historical Glen Canyon Dam and Imperial Dam Releases

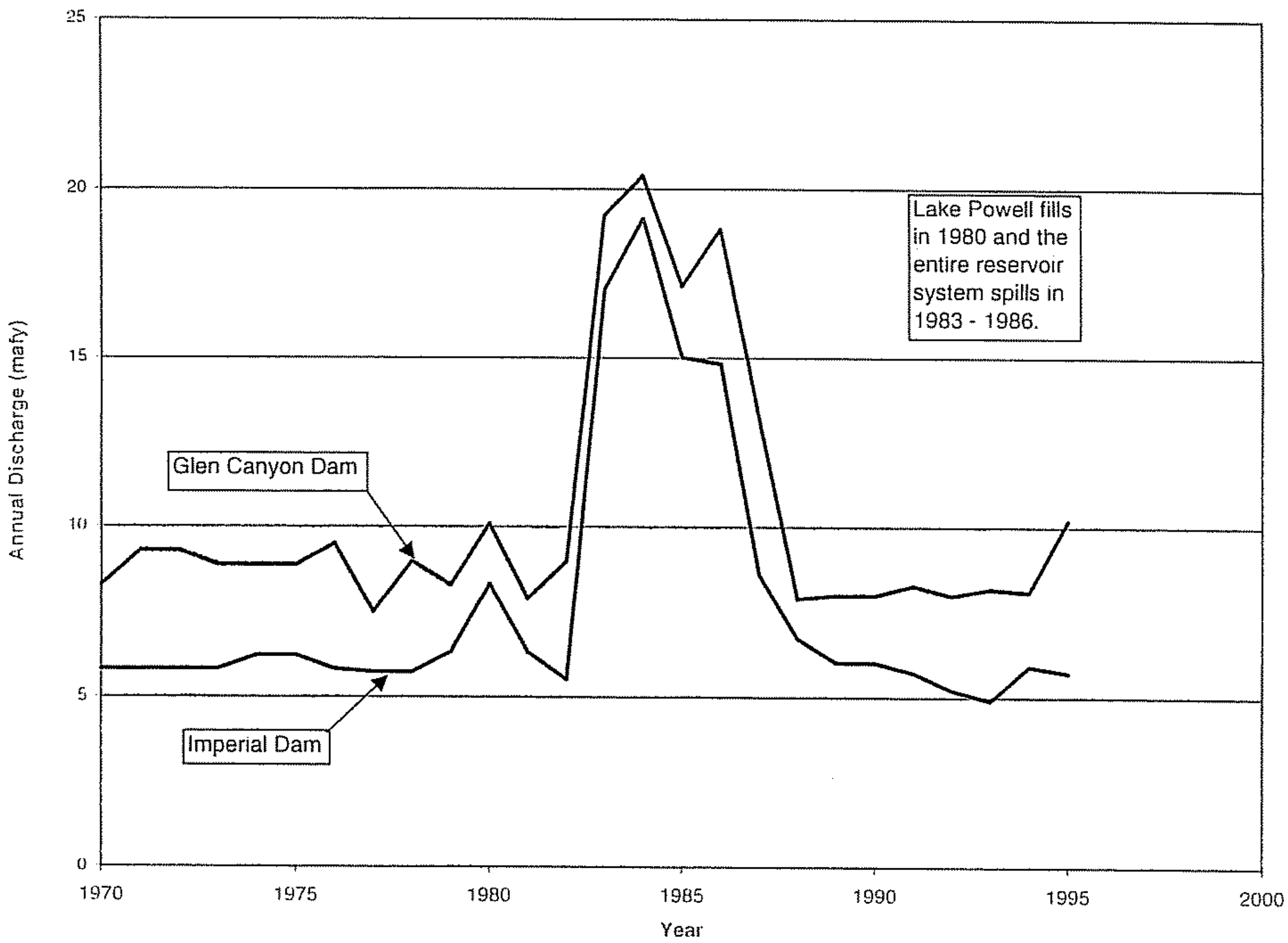
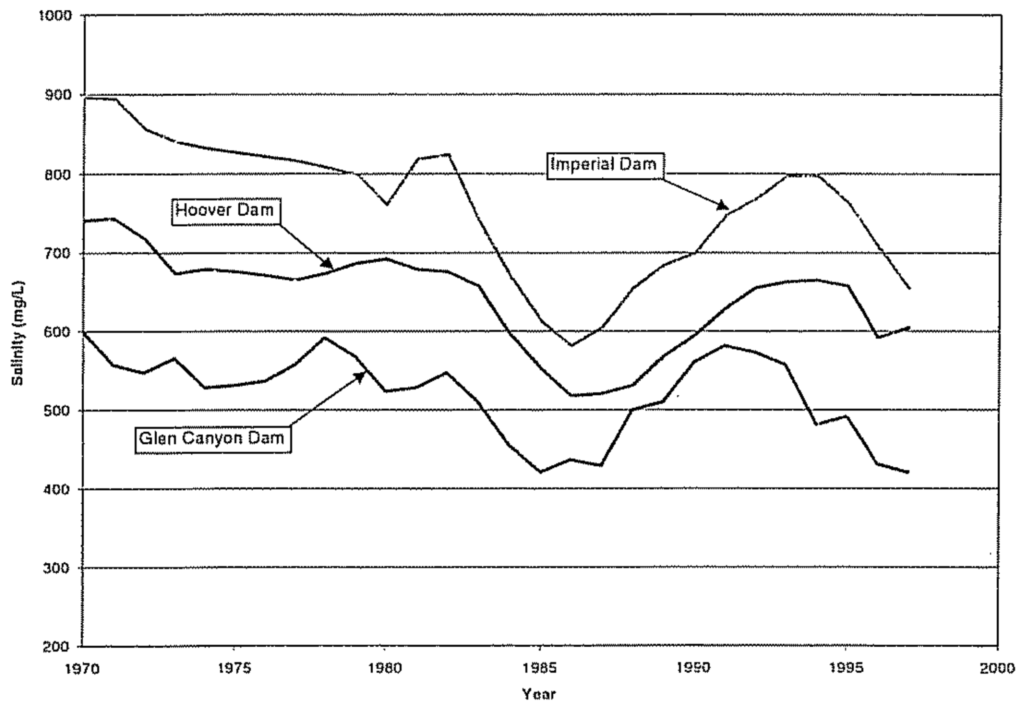


Figure 3.5-3
Historical Salinity Concentrations of Releases
from Glen Canyon, Hoover, and Imperial Dams



These criteria applied only to the lower portion of the Colorado River from Hoover Dam to Imperial Dam. Below Imperial Dam, salinity control is a federal responsibility to meet the terms of Minute 242 to the U.S.-Mexico Water Treaty of 1944. Minute 242 requires that salinity concentrations upstream of Mexico's diversion be no more than 115 mg/l ± 30 mg/l TDS higher than the average salinity of water arriving at Imperial Dam.

In 1974, the Colorado River Basin Salinity Control Act (P.L. 93-320) was enacted. The Act contains two Titles: 1) Title I provides the means for the United States to meet its commitment to Mexico; and 2) Title II creates a salinity control program within the Colorado River Basin in order that the numeric criteria will be maintained while the Basin States continue to develop their apportionment of Colorado River water.

The federal/state salinity control program is designed to maintain the flow-weighted average annual salinity at or below the numeric criteria. The program is not intended to counteract short-term salinity variations resulting from short-term water supply. Federal regulations provide for temporary increases above the criteria due to natural variations in flows.

The seven Basin States acting through the Forum reviews the numeric criteria and plan of implementation every three years and makes changes in the plan of implementation to accommodate changes occurring in the Basin States. The latest review was in 1999. The review is currently undergoing adoption by the Basin States and approval by EPA.

At each triennial review, the current and future water uses are analyzed for their impact on the salinity of the Colorado River. If needed, additional salinity control projects are added to the plan to assure compliance with the standards.

The need for one or more additional salinity control projects is determined by monitoring the salinity of the river and making near-term projections of changes in diversions from and return flows to the river system. When an additional project is needed, it is selected from a list of potential projects that have undergone feasibility investigation. A proposal to implement the project is made through coordination with the Basin States. In selecting a project, considerable weight is given to the relative cost-effectiveness of the project. Cost-effectiveness is a measure of the cost per ton of salt removed from the river system or prevented from entering the river system. Other factors are also considered, including environmental feasibility and institutional acceptability.

It is estimated that 1,478,000 tons of salt will need to be removed or prevented from entering the Colorado River system to maintain the salinity concentration at or below the criteria through 2015. To date, over 720,000 tons have been controlled and an additional 756,000 tons will need to be controlled through 2015.

3.5.2.2.3 General Municipal, Industrial, and Agricultural Effects of Increased Salinity Concentrations

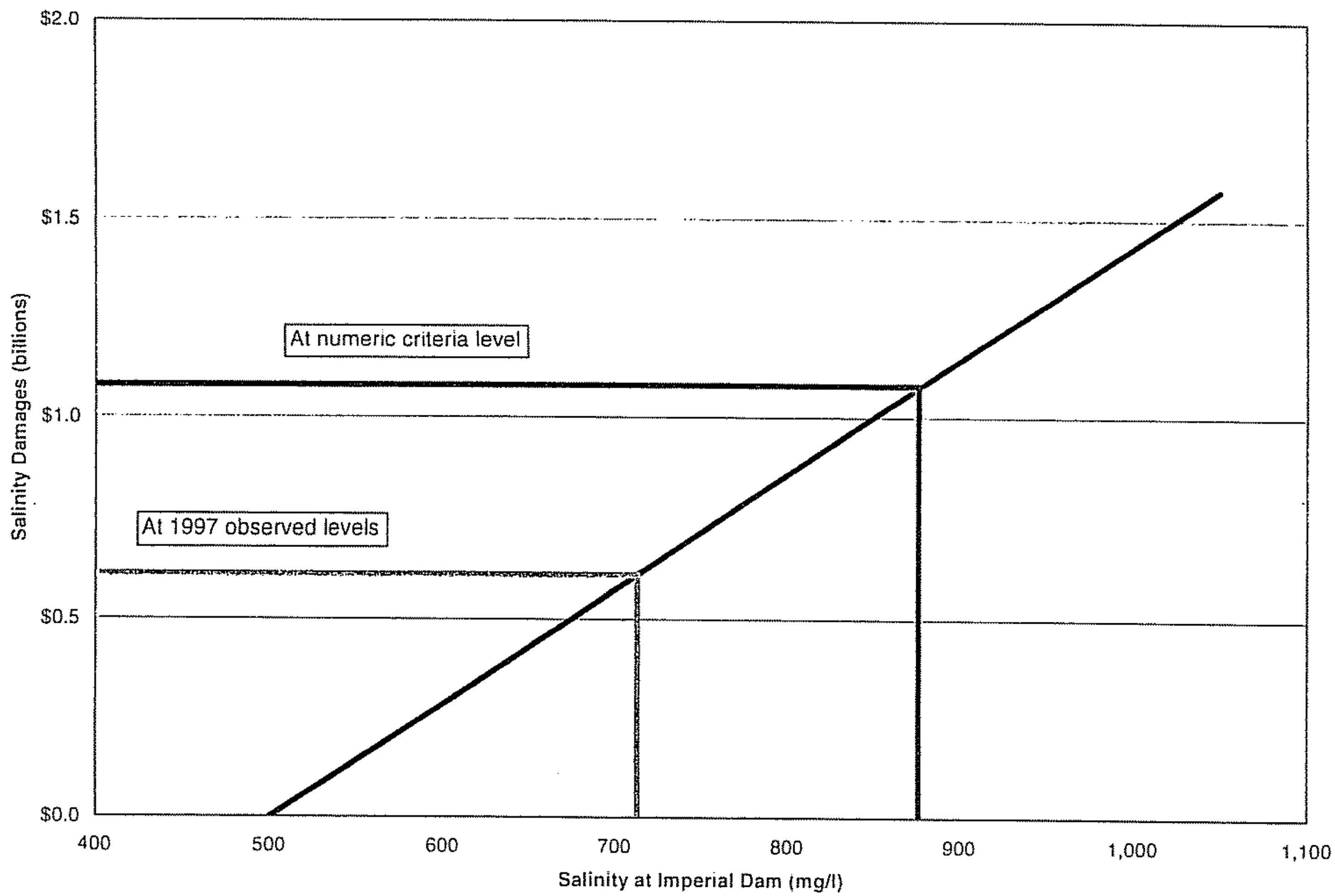
High salinity concentrations can cause corrosion of plumbing, reduce the life of water-using appliances, and require greater use of cleaning products. Industrial users incur extra water treatment costs. Increased salinity in drinking water can create unpleasant taste, often resulting in the purchase of bottled water or water treatment devices. Agriculture experiences economic losses from high salinity through reduced crop productivity and the need to change from less salt-tolerant high value crops, to more salt-tolerant low value crops. Increased salinity can also require more extensive agricultural drainage systems.

High salinity is a significant constraint to water recycling and groundwater replenishment programs. Compliance with regulatory requirements imposed by local water quality management programs to protect groundwater supplies can add significantly to the economic impacts. Restrictions have been placed on reuse or recharge of waters that exceed specific salinity levels. Such restrictions significantly constrain groundwater replenishment programs and wastewater reuse programs. Should salinity of the Colorado River increase, these regulatory actions could create a need for more expensive water treatment processes, such as reverse osmosis, prior to disposal or reuse. If disposal is selected, additional water supplies would need to be developed to meet demands that could have been met by water reuse.

Reclamation has determined that the economic damages from Colorado River salinity in the three Lower Division states served by Colorado River water amount to $2.5 million per mg/l. Figure 3.5-4 shows the relationship between costs of damages and salinity concentrations.

Therefore it is assumed for this analysis that the baseline conditions will reflect the numeric criteria at each station of interest (below Hoover Dam, below Parker Dam, and at Imperial Dam).

Figure 3.5-4
Estimated Cost of Damages Associated with Increased Salinity Concentrations



3.5.2.3 ENVIRONMENTAL CONSEQUENCES

The effects of the alternatives on the salinity of Colorado River water focus on their differences from baseline conditions. Since the current model configuration does not include any salinity control projects beyond those currently in place, modeling of baseline conditions indicates increases in salinity due to projected increased water consumption in the Upper Basin. However, in practice, these increases would be offset by salinity control projects that would continue to be implemented.

Tables 3.5-1 and 3.5-2 present these differences for years 2016 and 2050, respectively. The TDS values represent the mean values for the flow-weighted annual averages for the given year. The first column under each monitoring station heading in the tables presents the model projected TDS concentrations under the five alternatives calculated by applying the difference to the baseline TDS level. The second column presents the difference between the values for each alternative compared with baseline conditions.

As shown in Table 3.5-1, there is, in general, very little effect on TDS (less than one percent) due to interim surplus criteria in the year 2016. The exception is the decrease at Imperial Dam for the California Alternative of 19 mg/l (about 2.2 percent). This is due to the assumption in the model of an additional transfer from PVID to MWD of 100,000 af during normal and Tier 3 surplus conditions, which reduces the salt pickup in the return flows.

In general, the surplus alternatives tend to decrease TDS values slightly. These decreases are due to increased equalization releases from Lake Powell relative to baseline.

As shown in Table 3.5-2, interim surplus criteria have no effect on TDS values by the year 2050, with the exception of the PVID to MWD transfer assumed in the California Alternative.

3.5.3 LAKE MEAD WATER QUALITY AND LAS VEGAS WATER SUPPLY

This analysis addresses potential impacts of interim surplus criteria alternatives on water quality in Lake Mead, and potential changes to water quality and levels of contaminants at the SNWA intakes. This is a qualitative analysis based on system modeling and existing limnological studies.

3.5.3.1 METHODOLOGY

Evaluation of the environmental consequences of each operational alternative to Lake Mead water quality and Las Vegas water supply are based on a qualitative assessment of existing limnological and hydrodynamic data, and hydrologic modeling as discussed in Section 3.3. Each interim surplus criteria alternative was modeled for comparison to baseline projections. Modeling focused on the probability of decreased Lake Mead

Table 3.5-1
Estimated Colorado River Salinity in 2016
Unit: Total Dissolved Solids (mg/l)

Alternative	Below Hoover Dam		Below Parker Dam		At Imperial Dam	
	Value	Departure from Baseline	Value	Departure from Baseline	Value	Departure from Baseline
Baseline Conditions[1]	723	NA	747	NA	879	NA
Basin States	719	-2	737	-2	879	0
Flood Control	723	0	745	-0	879	0
Six States	719	-2	738	-2	881	0
California	712	-5	734	-5	853	-19
Shortage Protection	715	-4	736	-4	872	-3

1 Baseline conditions assume compliance with the numeric criteria at the locations cited.

Table 3.5-2
Estimated Colorado River Salinity in 2050
Unit: Total Dissolved Solids (mg/l)

Alternative	Below Hoover Dam		Below Parker Dam		At Imperial Dam	
	Value	Departure from Baseline	Value	Departure from Baseline	Value	Departure from Baseline
Baseline Conditions[1]	723	NA	747	NA	879	NA
Basin States	723	0	747	0	877	0
Flood Control	723	0	747	0	879	0
Six States	723	0	747	0	878	0
California	722	-1	745	0	857	-24
Shortage Protection	722	-1	747	0	876	0

1 Baseline conditions assume compliance with the numeric criteria at the locations cited

surface elevations, which could exacerbate effects of discharge of Las Vegas Wash water into Boulder Basin.

Assessment of potential effects on water quality of Lake Mead, including consideration of Las Vegas Wash inflow on the SNWA intake, relied primarily on system modeling information associated with the probability of future Lake Mead surface elevations. Previous studies of Lake Mead were also an important source of information, particularly those focusing on Boulder Basin, Las Vegas Wash, and hydrodynamics potentially affecting intake water quality.

As discussed in Section 3.3, modeling identified probabilities associated with surface water elevations under baseline conditions as well as projections associated with implementation of the interim surplus criteria alternatives over a 50-year period. As discussed previously, model output utilized for this water quality analysis assumes shortage determinations would occur, if necessary, to protect a surface elevation of 1083 feet msl, which is the Lake Mead minimum power pool elevation. The primary SNWA intake at Saddle Island is at 1050 feet msl, and the secondary intake is at 1000 feet msl. Thus, assuming a strategy to protect 1083 feet msl also provides a level of protection to SNWA's intake water quality.

As discussed below, contaminant dilution and lake water quality are directly proportional to lake volume. As such, a critical element in this assessment is a comparison of projected Lake Mead volumes under the five action alternatives relative to baseline conditions. Using hydrologic modeling output, median Lake Mead volumes and surface areas were identified for each of the alternatives associated with projected reservoir elevations under the median modeled probabilities. Modeling results indicating these parameters were then developed for the years 2016, 2026, 2036, and 2050. Separate comparisons were then made of the volume and surface area for each alternative as compared to baseline conditions.

3.5.3.2 AFFECTED ENVIRONMENT

The focus of this section is a description of the affected environment related to Lake Mead water quality and the SNWA intake locations, with specific consideration of hydrodynamics of the Colorado River Basin, limnology and water quality (factors that may be influenced by implementation of interim surplus criteria alternatives).

3.5.3.2.1 General Description

Lake Mead is a large mainstream Colorado River reservoir in the Mohave Desert, within the States of Arizona and Nevada as shown on Map 3.2-1. Lake Mead, formed in 1935 following the construction of Hoover Dam, is the largest reservoir in the United States by volume (26 maf active storage). At full pool (reservoir elevation 1221 feet msl), Lake Mead extends 108 miles from Black Canyon (Hoover Dam) to Separation Canyon at the upstream end. Lake Mead has four large sub-basins including Boulder, Virgin, Temple and Gregg. Between these basins are four narrow canyons: Black, Boulder, Virgin and Iceberg. Over 170,000 square miles of the Colorado River Basin watershed are located above Hoover Dam. Boulder Basin, SNWA intake locations and the Las Vegas Wash are shown on Map 3.5-1.

The Muddy and South Virgin mountains border the reservoir on the north, and the Virgin and Black mountains and various desert hills border the reservoir on the south. The shoreline is extremely irregular with a Shoreline Development Value (SLD) of 9.7 (Paulson and Baker, 1981). SLD is the ratio of the length of the shoreline of a lake or reservoir to the length of the circumference of a circle with an area equal to that of the lake (Wetzel, 1975). The shoreline includes several large bays, including Las Vegas and Bonelli, and numerous coves. The principal morphometric characteristics of Lake Mead are summarized below in Table 3.5-3.

Table 3.5-3
Morphometric Characteristics of Lake Mead

Parameter	Units	Value
Normal operating level (spillway crest)	feet	1,205
Maximum depth	feet	590
Mean depth	feet	180
Surface area	square miles	231
Volume (including dead storage)	maf	30
Maximum length	miles	108
Maximum width	miles	17
Shoreline development	Index Value	9.7
Discharge depth	feet	310
Annual discharge (approximate)	maf	10
Replacement time at maximum operating level	years	3.9

Derived from Interior (1966), Lara and Sanders (1970), Hoffman and Jonez (1973)

LaBounty and Horn (1997) conducted a study of the influence of drainage from the Las Vegas Valley on the limnology of Boulder Basin that is highly relevant to the issue addressed in this section. Unless otherwise noted, the descriptions of reservoir characteristics, hydrodynamics, and general limnology of Lake Mead are drawn from this study.

The Colorado River contributes about 98 percent of the annual inflow to Lake Mead; the Virgin and Muddy rivers and Las Vegas Wash provide the remainder. Annual flows from Las Vegas Wash are approximately 155,000 af, providing the second highest inflow into Lake Mead. Discharge from Hoover Dam is hypolimnetic and occurs 285 feet below the normal operating shown above (1205 feet msl). Average annual discharge is approximately 10 maf.

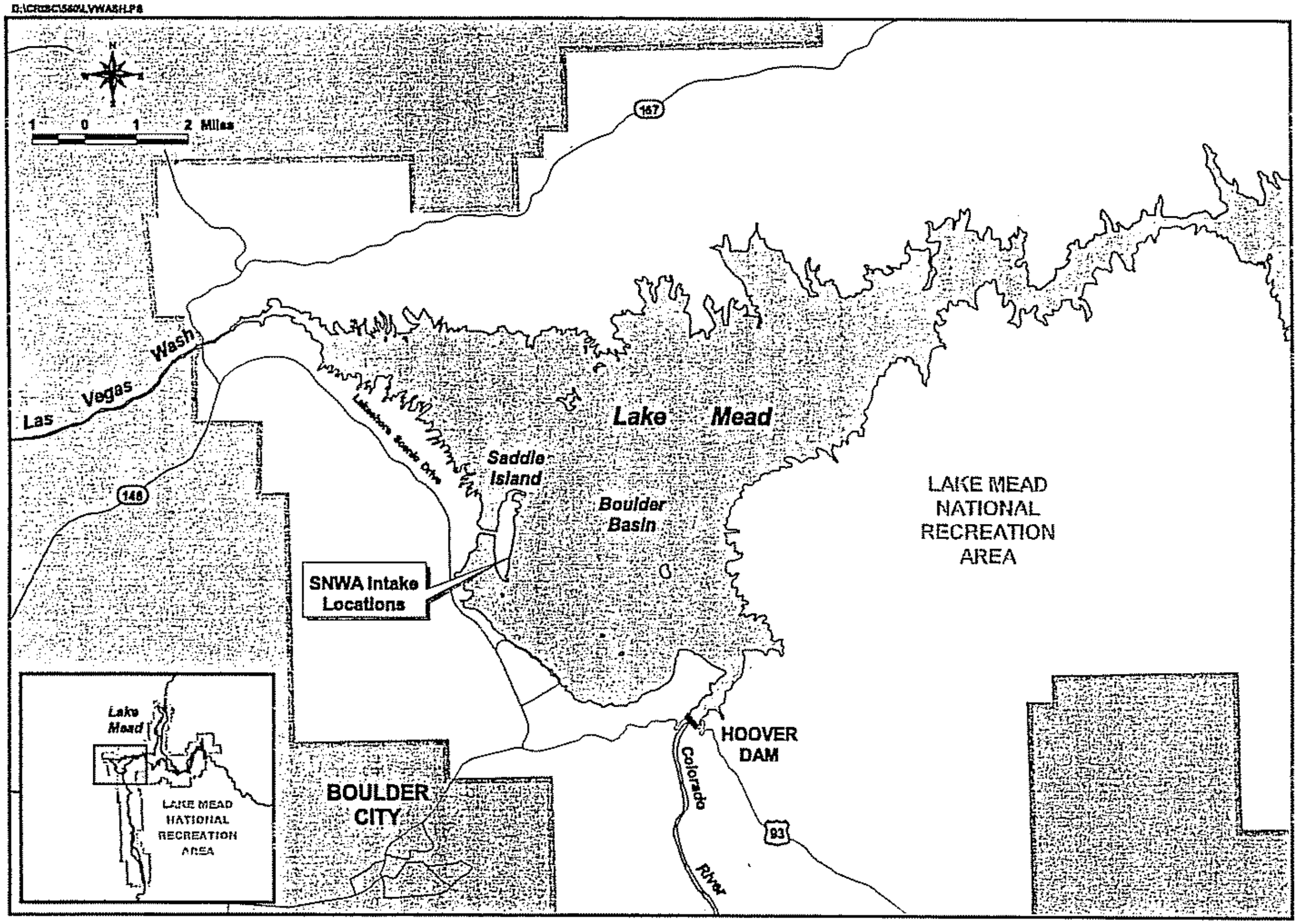
Boulder Basin, the lowermost basin of Lake Mead, receives all nonpoint surface and groundwater discharges and treated effluent from the Las Vegas Valley and municipal wastewater treatment facilities via drainage from Las Vegas Wash into Las Vegas Bay. Boulder Basin is 9.3 miles wide from Boulder Canyon to Hoover Dam (Black Canyon), and the distance from the confluence of Las Vegas Wash to Hoover Dam is approximately 9.9 miles. The historical Colorado River channel lies along the eastern side of Boulder Basin.

Due to effects of urban runoff and treatment plant effluents on the discharge through Las Vegas Wash (discussed later in this section), Boulder Basin has the highest nutrient concentrations in the Lake Mead system (Paulson and Baker, 1981; Prentki and Paulson, 1983). This is in contrast to the normal upstream-downstream decrease in the pattern of productivity more typical of reservoirs, and results in several limnological features within Boulder Basin that are normally associated with upstream reaches (Kimmel et al., 1990).

Overall, Lake Mead is mildly mesotrophic based on several classification indices (Vollenweider 1970; Carlson 1977), including chlorophyll *a* concentration and secchi transparency measurements. Chlorophyll concentration is a measure of algal biomass and can, therefore, be interpreted as an index of lake productivity. Secchi disk measurements are used to determine the depth to which light penetrates lake water and help to establish the euphotic zone which marks that area of a lake where primary productivity (energy production by photosynthesis) occurs.

Due to abundant nutrient input into Las Vegas Bay, chlorophyll concentrations have been measured greater than 100 milligrams per cubic meter (mg/m^3). Secchi transparency readings of less than two feet have been measured in the inner bay (LaBounty and Horn, 1997). However, secchi transparency increases to over 16 feet, and chlorophyll *a* is reduced by 90 percent within the first 2.6 miles from the Las Vegas Wash inflow. These findings suggest that Boulder Basin is a relatively isolated embayment and that it is much more productive than the lake as a whole.

Map 3.5-1
Las Vegas Wash and SNWA Lake Mead Intake Facilities at Saddle Island



The Federal Water Pollution Control Act (Clean Water Act) Amendments of 1972 and 1977 require the control of all sources of water pollution in meeting the goals of the Act. Section 208 of the Act requires that all activities associated with water pollution problems are planned and managed through an integrated area-wide water quality management program. It also defines the schedule and scope of area-wide wastewater treatment management plans. The 1997 Las Vegas Valley 208 Water Quality Management Plan Amendment certified by the State of Nevada and EPA, is a 20-year plan that comprehensively addresses the quality and quantity of the Valley's point source (discharges from wastewater treatment facilities) and non-point sources (groundwater, stormwater issues, Las Vegas Wash, agricultural diffuse sources), and revisions of water quality standards.

The water quality requirements currently being met by the wastewater discharges of the Las Vegas Valley have a long history. Beginning in the 1950s with requirements for secondary treatment, through the 1970s and the promulgation of the Clean Water Act, and into the 1990s with more advanced nutrient removal requirement, the quality and volume of treated wastewater discharged to Lake Mead has continued to increase and will continue to meet standards into the future through the Section 208 process (Clark County, 1997).

The Lake Mead Water Quality Forum, established by the Nevada Division of Environmental Protection (NDEP), has been identified in the Plan as an avenue for coordinated research opportunities and solutions to the water quality issues that face Las Vegas Valley and Lake Mead in the future. The forum is comprised of federal, state and local agencies with a vested interest in Lake Mead's water quality. The Lake Mead Water Quality forum is responsible for issue identification, coordination and defining the process approach in identifying issues regarding water quality and potential impacts to the water supply. The Las Vegas Wash Coordination Committee (LVWCC) is comprised of more than two dozen members of local, state, and federal agencies, business owners and members of the public. The LVWCC was tasked with the support, development and implementation of the Las Vegas Wash Comprehensive Adaptive Management Plan (LVWCAMP). The planning phase of the LVCAMP is now complete, and various actions presented in the plan are currently in progress to restore the wash, its wetlands, and its ability to improve the quality of return flows into Lake Mead. Reclamation is an active member of both of these groups and has been independently funding research on Lake Mead water quality prior to their formation and is now a funding partner with other agencies for ongoing studies on the Wash and Lake Mead. Water quality in Lake Mead and Las Vegas Wash are the subject of numerous articles and the chemical and physical analyses of raw and treated Lake Mead source water is published on SNWA's website (http://www.snwa.com).

3.5.3.2.2 Lake Mead Water Quality and Limnology

Water quality of Lake Mead and the Colorado River is alkaline with a pH of 8.3 and an average concentration of TDS of approximately 700 mg/l. Chemical characteristics of the river at the inflow to Lake Mead, near the outflow at Hoover Dam, and at Lake Mohave are shown below in Table 3.5-4.

Table 3.5-4
Chemical Characteristics of Colorado River

Parameter	Units	Gage Station Location[1]		
		Grand Canyon	Hoover Dam	Davis Dam
pH		8.0	7.7	8.0
Conductivity	umho/cm^2	945	1086	1089
Total Dissolved Solids	mg/l	617	705	714
Calcium	mg/l	74	86	84
Magnesium	mg/l	26	28	29
Potassium	mg/l	4.1	4.9	5.0
Bicarbonate	mg/l	170	163	157
Sulfate	mg/l	228	283	293
Chloride	mg/l	79	85	87
Silica	mg/l	7.0	8.3	7.8
Nitrate	mg/l	.50	.41	.28
Phosphate	mg/l	.010	.013	--

[1]USGA data, average for October 1975 – September 1976

The principal constituents of TDS are the anions of sulfate, carbonate and chloride and the cations of sodium, calcium, magnesium and potassium. Nitrate concentrations are moderate (0.28 to 0.50 mg/l), but phosphorus is extremely low (0.01 to 0.03 mg/l). Silica is present in very high concentrations (7.0 to 8.3 mg/l).

Limnological investigations of Lake Mead have found that 80 percent of the inorganic nitrogen within the lake is provided by the Colorado River, and that Las Vegas Wash contributes 70 percent of the inorganic phosphorus (Paulson, Baker, Deacon, 1980). The Upper Basin of Lake Mead was found to be phosphorus-limited, and the Lower Basin nitrogen-limited during the summer. Equal proportions of nitrogen and phosphorous were retained in the Upper Basin of Lake Mead, but nitrogen retention decreased to seven percent, and phosphorus to 33 percent in the Lower Basin. Additionally, the high nitrate loss from Hoover Dam greatly reduced nitrogen retention in the Lower Basin of Lake Mead.

In 1978 the EPA estimated that Lake Mead retained 93 percent of the total phosphorus input versus 52 percent of total nitrogen (EPA, 1978). Phosphorus concentrations are low in the Upper Basin of the lake due to the low input from the Colorado River, a result of sediment trapping that occurs upstream within Lake Powell.

As recently as 1998, new contaminants to Lake Mead have been discovered as a part of the nonpoint pollutant load of Las Vegas Wash (EPA, 2000). Perchlorate has been detected in the water of the Colorado River and Lake Mead. Ammonium perchlorate is manufactured as an oxygen-adding compound in solid rocket fuel propellant, missiles and fireworks. The EPA identified two facilities that manufactured ammonium perchlorate in Henderson, Nevada, that were found to have released perchlorate to groundwater, resulting in four to 16 parts per billion (ppb) concentrations in Lake Mead and the Colorado River (EPA, 2000).

The NDEP and the SNWA have initiated a collective investigation to locate and clean up perchlorate in the Colorado River system in coordination with the EPA. The primary objectives are to locate the source, the groundwater discharge sources, clean it up, and prevent it from becoming a problem in the future. The EPA has not established concentration levels of perchlorate because it is not considered a water contaminant. However, California's Department of Health Services and NDEP have established an interim action level of 18 ppb for drinking water. Concentrations lower than 18 ppb are not considered to pose a health concern for the public, including children and pregnant women. All SNWA drinking water has tested at 11 ppb or lower for perchlorate. Average perchlorate values for water samples collected at their intake were 9.5 ppb between June 1999 and August 2000. Perchlorate is not regulated under the Federal Safe Drinking Water Act and thus information is limited regarding its potential health risks but it is known to affect how the thyroid processes iodine and is used to treat Graves Disease. In March 1998, perchlorate was added to the Contaminant Candidate List as part of the Safe Drinking Water Act due to the concern over potential public health impact, need for additional research in areas of health effects, treatment technologies, analytical methods, and more complete occurrence data.

The SNWA identified a major surface flow of perchlorate-laden water from a groundwater discharge point along Las Vegas Wash in late 1999. Other discharge points are being investigated. Kerr-McGee Chemical Company, with the NDEP, and Reclamation as the land management agency, worked together to begin intercepting that surface flow for treatment. This program is now underway and has significantly reduced the amount of perchlorate entering the Las Vegas Wash, Lake Mead, and the Colorado River. This remediation program will continue into the future and will continue to reduce perchlorate contamination in groundwater and Colorado River water in Lake Mead and downstream.

In a soon to be published article on contaminants found in Lake Mead fish by Dr. Jim Cizdziel, University Nevada Las Vegas, only one fish sampled of approximately 300 fish tissues sampled for mercury indicated results above the Federal Department of Agriculture's 1.0 ppm level of concern. During this 1998-1999 investigation for metals found in Lake Mead fish tissue, most fish sampled for mercury were less than 0.5 ppm (Pollard, 1999). After reviewing this work, the State of Nevada has decided not to issue any fish consumption advisories for any contaminates for Lake Mead fish (Pohlmann, 1999).

The rate and volume of inflow from the Colorado River are major determinants of the limnology of Lake Mead, with minor contributions to volume coming from the Virgin and Muddy rivers and the Las Vegas Wash (see Table 3.5-5). Due to its lower conductivity within Lake Mead, Colorado River flows can be identified through the reservoir. Flows into Lake Mead average approximately 17,900 to 21,400 cfs. During a seven-day controlled flood in 1996, inflows of 44,600 cfs resulted in a three-foot rise in surface elevation. Flows of this magnitude influence reservoir limnology of Lake Mead well into Boulder Basin (LaBounty and Horn, 1997).

Table 3.5-5
Hydraulic Inputs for Lake Mead

Input	Flow (af)	% of Total
Colorado River	8,800,000	98
Virgin River	92,000	1
Las Vegas Valley Wash	59,000	0.60
Muddy River	29,000	0.34
TOTAL INPUT	**9,000,000**	**100**

Derived from USGS data from October 1975 – September 1976

The two major outflows from Lake Mead are both in Boulder Basin: Hoover Dam and the SNWA intake. Hoover Dam is operated for flood control, river regulation and power production purposes. The operating elevation for Hoover Dam powerplant ranges from 1083 feet to a maximum elevation of 1221 feet msl. The dam's four intake towers draw water from the reservoir at approximate elevations 1050 and/or 900 feet msl to drive the generators within the dam's powerplant. SNWA pumps water from two adjacent intakes located at Saddle Island that operate down to elevations of 1050 feet and 1000 feet msl. Hoover Dam outflows vary on a daily basis from approximately 2000 cfs to 50,700 cfs. Capacity of the SNWA intake is 600 cfs. Despite its much smaller volume, the SNWA intake has been shown to influence deep water currents near the entrance to Las Vegas Bay (Sartoris and Hoffman, 1971).

LaBounty and Horn (1997) cite the rarity of complete turnover in Lake Mead due to the great depth (590 feet), and relatively constant temperature gradient. The thermal regime over the period of 1990 through 1996 was characterized by surface temperatures of 14 degrees Celsius (°C) in December and January to over 30°C in August. Seasonal thermoclines range from 50 feet in early summer to 100 feet in late summer. Hypolimnetic temperatures remain near 12°C year-round. Though full reservoir turnover seldom occurs, turnover occurs to a depth of approximately 200 to 230 feet in January and February, a sufficient depth for complete mixing in Las Vegas Bay.

As with other reservoirs, dam operation exerts a great influence on the water quality and ecology of the system (Thornton, 1990). The hydrodynamics of this large reservoir are complex and not completely understood. Each basin within Lake Mead is ecologically unique, and therefore responds differently to the inflow-outflow regime. Furthermore, the different sources of water entering Lake Mead often retain their identity for substantial distances into the reservoir and do not necessarily mix completely with the rest of the water column (Ford, 1990). This spatial heterogeneity can lead to significant underestimates of actual water retention time, conveyance and fate of materials transported into the reservoir.

3.5.3.2.3 Hydrodynamics of Lake Mead and Boulder Basin

The Colorado River, Virgin and Muddy rivers and Las Vegas Wash all form density currents in Lake Mead (Anderson and Pritchard, 1951; Deacon and Tew, 1973; Deacon 1975, 1976, 1977; Baker et al., 1977; Baker and Paulson, 1978). Anderson and Pritchard (1951) conducted a detailed investigation of density currents in 1948-1949 using temperature and TDS relationships to trace the river inflows. They found that the Colorado River flowed along the bottom of the old river channel in winter (January-March). The underflow was detectable well into the Virgin Basin and at times extended to Boulder Basin. The underflow created a strong convergence at the point where river water flowed beneath lake water. Up-lake flow of surface water occurred due to frictionally induced, parallel flow of lake water (entrainment) along the boundary of the cold river inflow. This produced a large circulation cell in the Upper Basin of Lake Mead, as surface water was pulled up-lake to replace that entrained by the underflow.

Hydrodynamics within Las Vegas Bay have also been the subject of research and are particularly important from the standpoint of potential interactions between Las Vegas Wash water and intake water quality. LaBounty and Horn (1997) provide an excellent discussion of flow patterns in this area of Lake Mead. These authors cite unique signatures of both Colorado River water and Las Vegas Wash water that allow mapping of higher conductivity intrusions from Las Vegas Wash into Boulder Basin. Depending on conditions, the intrusion can be measured for over five miles into Lake Mead. Seasonally, the Las Vegas Wash intrusion is deepest in January and February (130 to 200 feet) and shallowest in early spring (33 to 50 feet).

Water quality in Las Vegas Wash, and ultimately in Boulder Basin, is heavily influenced by urban runoff, as well as the treated effluent from three major sewage treatment facilities upstream. Historically, flows in this basin drained wetlands, which allowed for natural cooling and nutrient removal. Flows today are warmer and have doubled in volume over the last 15 years, from 110 cfs to 215 cfs (LaBounty and Horn, 1997). These factors have tended to force the intrusion higher in the water column of Las Vegas Bay.

The existence of contaminants in sediments and fish tissue in Las Vegas Bay, and poor water quality has been well documented (LaBounty and Horn, 1996; Roefer et al., 1996; Bevans et al., 1996). LaBounty and Horn (1997) cite the relatively close proximity of the SNWA intake at Saddle Island to potential intrusions of the Las Vegas Wash, and conclude that changes in hydrodynamics of the basin (i.e., due to drought or management actions) are critical considerations in assessing effects of the Las Vegas Wash on drinking water quality.

3.5.3.3 Environmental Consequences

3.5.3.3.1 General Effects of Reduced Lake Levels

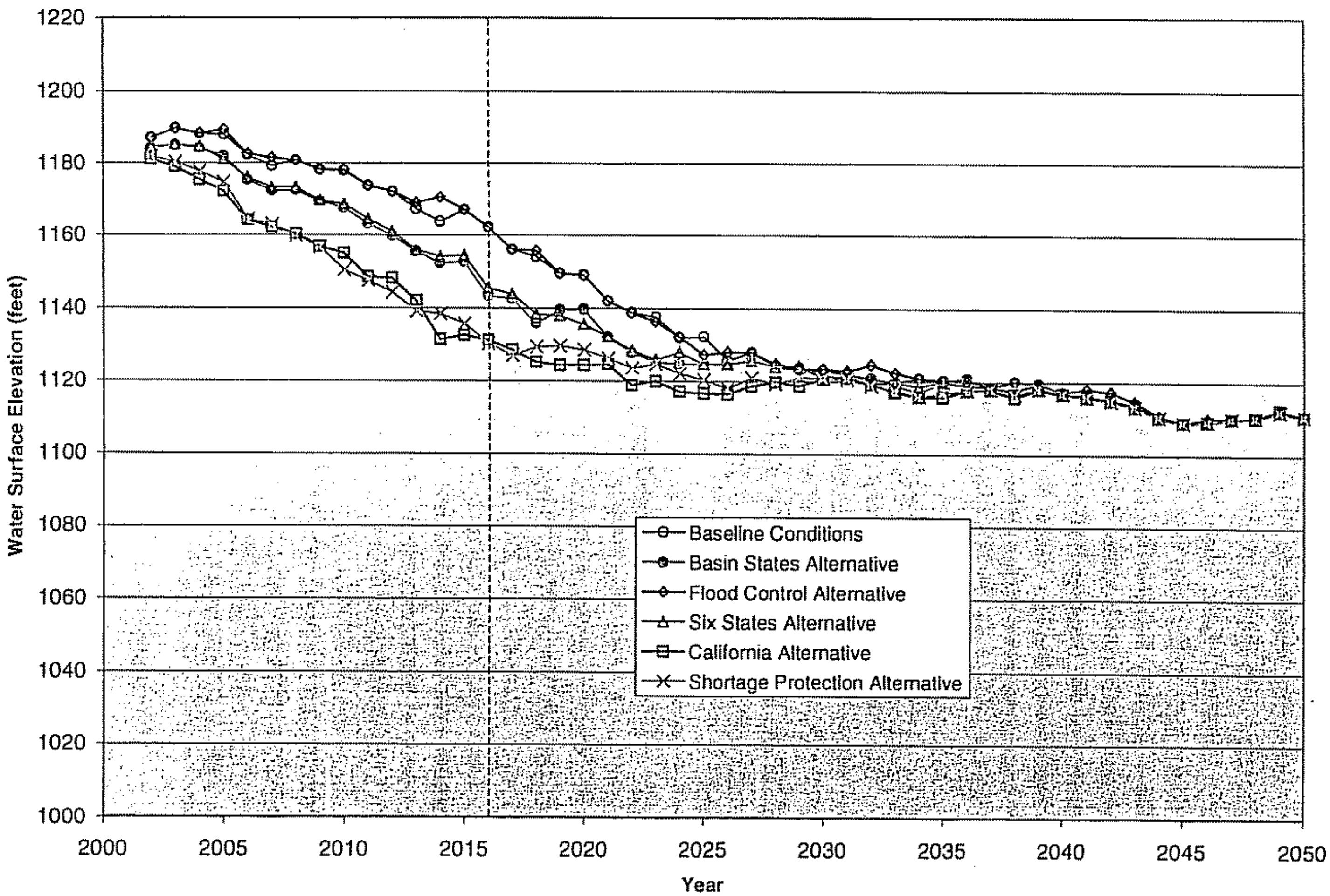
This section presents potential water quality changes in Lake Mead associated with reductions in lake levels, and potential effects of these changes on the concentration of Las Vegas Wash water at SNWA water supply intakes. In addition, this section addresses general limnological changes in Lake Mead that may occur under each alternative.

It is important to note that estimates of potential changes in Lake Mead surface elevations are based on system modeling discussed in Section 3.3. Water quality modeling has not been conducted as a part of this investigation; however, literature review and assumptions with regard to Las Vegas Wash mixing in the Boulder Basin under various Lake Mead elevations have been used to estimate potential future water quality conditions.

Results of model runs conducted for this analysis indicate that projections of baseline conditions and each of the interim surplus criteria alternatives indicate increased potential over time for the occurrence of declining Lake Mead surface elevations within and beyond the interim 15-year period, as indicated by the plots of median elevations on Figure 3.5-5.

The potential degradation of SNWA intake water is not demonstrated quantitatively in this FEIS, rather the expectation of degradation is based on the assumption that decreasing lake levels, and therefore lake volume and surface area, could result in decreased water quality and, more specifically, increased concentration of Las Vegas Wash inflow at the intake locations. The potential effects associated with Lake Mead elevation declines are described below, and are followed by a tabular comparison of the projected Lake Mead volume and surface area changes under the alternatives and baseline conditions.

Figure 3.5-5
Lake Mead End-of-Year Water Elevations
Comparison of Surplus Alternatives to Baseline Conditions
50th Percentile Values



3.5.3.3.1.1 Volume Reduction

Reduction in the volume of Lake Mead would likely have effects on lake water quality and, potentially, on water quality withdrawn by SNWA. These effects occur as a result of changes in mixing patterns in Boulder Basin. Given the hydrodynamics of Boulder Basin associated with the relatively confined nature of the embayment, effects of reduction in volume of Lake Mead would likely be disproportionately greater in Boulder Basin than in the lake as a whole. LaBounty and Horn (1997) cite the importance of salinity and thermal gradients in determining the extent of intrusion of the Las Vegas Wash into Boulder Basin. Lower lake volumes could increase the overall salinity of the Boulder Basin, thereby lowering the differential between lake water and inflows of the Las Vegas Wash. This in turn may act to disperse the intrusion, causing a more diffuse flow from Las Vegas Wash, a greater concentration of nutrients and contaminants throughout Boulder Basin, and greater availability of nonpoint contaminants in the vicinity of the SNWA intakes. Clark County's 208 Water Quality Plan certified by EPA and NDEP, regulates the quality and quantity of discharges from wastewater treatment facilities that flow into Lake Mead. These discharges currently meet standards and will do so into the future (Clark County, 1997). The SNWA is in the process of upgrading its raw water treatment facilities and these state of the art facilities will be able to meet any treatment challenges from reduced reservoir levels caused by drought or declines from interim surplus alternatives.

3.5.3.3.1.2 Tributary Water Quality

Lower water surface elevations in Lake Mead could also impact the quality of tributary flows from the Las Vegas Wash, Virgin and Muddy rivers. These effects would be a result of longer channels, and thus, longer travel times for influent streams. Potential effects on Lake Mead could include increased temperature due to warmer tributary flows. Higher evaporative losses and greater concentration of salts and contaminants may also occur in tributaries due to longer channels, leading to higher concentrations of pollutants in the Las Vegas Wash, and potentially greater concentrations of contaminants near the SNWA intakes. However, new riparian habitat development near the mouths and in these tributaries would likely develop and would be expected to offset impacts to tributary water quality. Restoration of the Las Vegas Wash wetlands will trap surface and groundwater contaminants, cool return flows and further improve the quality of return flows before it reaches Lake Mead.

3.5.3.3.2 Comparison of Baseline Conditions and Alternatives

Section 3.5.3.3.1, above, discussed the general water quality effects that may be expected given reduced Lake Mead surface elevations and volumes. The following sections compare predicted surface elevations, volume, and surface area of Lake Mead under baseline and alternative conditions. This analysis is based on system modeling results; specifically the 50 percent (median) probability elevations, as shown on Figure 3.5-5.

Characteristics of Lake Mead (elevation, volume, surface area) under baseline and alternative conditions are shown below for four selected years (i.e., years 2016, 2026, 2036 and 2050) within the modeled period, as shown in Table 3.5-6. A comparison of the percentage difference between the alternatives and baseline conditions is shown in Table 3.5-7. It should be noted that median elevations converge with the baseline condition towards the end of the period of analysis, resulting in minimal differences among the alternatives and baseline conditions in the year 2050.

3.5.3.3.2.1 Baseline Conditions

Baseline projections indicate a general trend of decreasing Lake Mead surface elevations, volume and surface area over the period of analysis, as shown above on Figure 3.5-5 and in Table 3.5-4. At the end of the interim surplus criteria period, 2016, the median elevation for Lake Mead is 1162 feet msl, a reduction of 15 feet from the surface elevation in 2002. The median baseline elevation in 2050 is 1111 feet msl for a total reduction in the median elevation of 76 feet over the entire period of analysis. This increased potential for lake level reductions would be expected to result in an increased potential for declining water quality of Lake Mead and associated effects on the SNWA intake (discussed in Section 3.5.3.3.1, above) over time under baseline conditions.

3.5.3.3.2.2 Basin States Alternative

Modeling of the Basin States Alternative indicates intermediate reductions in surface elevations, surface area and volume compared with baseline conditions in the year 2016 (when the largest differences among the alternatives are seen). The median elevation in year 2016 under the Basin States Alternative is 1143 feet msl, or 1.6 percent lower than baseline conditions in the same year, with reservoir volume approximate 12 percent lower than baseline conditions and volume becoming slightly greater than baseline by the year 2026 and slightly less than baseline in 2036. By the year 2050 no differences between this alternative and baseline conditions are present.

Table 3.5-6
Modeled Characteristics of Lake Mead Under Baseline and Alternative Conditions

Alternative	Elevation[1] (feet above msl)				Volume (maf)				Surface Area (x 1000 acres)			
	2016	2026	2036	2050	2016	2026	2036	2050	2016	2026	2036	2050
Baseline Conditions	1162.1	1125.7	1120.7	1110.6	17.9	13.9	13.4	12.5	120.2	99.8	97.6	93.6
Basin States	1143.3	1124.7	1120.4	1110.6	15.8	13.8	13.4	12.5	108.1	99.3	97.4	93.6
Flood Control	1162.1	1128.0	1118.9	1110.6	17.9	14.1	13.2	12.5	120.2	100.7	96.8	93.6
Six States	1145.5	1124.7	1120.5	1110.6	16.0	13.8	13.4	12.5	109.4	99.3	97.5	93.6
California	1131.2	1116.4	1117.6	1110.6	14.5	13.0	13.1	12.5	102.1	95.9	96.3	93.6
Shortage Protection	1130.2	1117.9	1117.6	1110.6	14.4	13.2	13.1	12.5	101.7	96.5	96.3	93.6

[1] Values shown are median elevations (50th percentile) for each year group.

Table 3.5-7
Modeled Comparisons of Alternatives to Baseline Conditions

Alternative	Elevation Change				Volume Change				Surface Area Change			
	2016	2026	2036	2050	2016	2026	2036	2050	2016	2026	2036	2050
Basin States	-1.6%	-0.1%	0.00%	0.00%	-11.7%	-0.7%	0.00%	0.00%	-10.1	-0.5	-0.2	0.00%
Flood Control	0.00%	0.2%	-0.2%	0.00%	0.00%	1.4%	-1.5%	0.00%	0.00%	0.9%	-0.8%	0.00%
Six States	-1.4%	-0.1%	0.00%	0.00%	-10.6%	-0.7%	0.00%	0.00%	-9.0%	-0.5%	-0.2%	0.00%
California	-2.7%	-0.8%	-0.3%	0.00%	-19.0%	-6.5%	-2.2%	0.00%	-15.1%	-3.9%	-1.3%	0.00%
Shortage Protection	-2.7%	-0.7%	-0.3%	0.00%	-19.6%	-5.0%	-2.2%	0.00%	-15.4%	-3.3%	-1.3%	0.00%

3.5.3.3.2.3 Baseline Conditions

Baseline projections indicate a general trend of decreasing Lake Mead surface elevations, volume and surface area over the period of analysis, as shown above on Figure 3.5-5 and in Table 3.5-4. At the end of the interim surplus criteria period, 2016, the median elevation for Lake Mead is 1162 feet msl, a reduction of 15 feet from the surface elevation in 2002. The median baseline elevation in 2050 is 1111 feet msl for a total reduction in the median elevation of 76 feet over the entire period of analysis. This increased potential for lake level reductions would be expected to result in an increased potential for declining water quality of Lake Mead and associated effects on the SNWA intake (discussed in Section 3.5.3.3.1, above) over time under baseline conditions.

3.5.3.3.2.4 Basin States Alternative

Modeling of the Basin States Alternative indicates intermediate reductions in surface elevations, surface area and volume compared with baseline conditions in the year 2016 (when the largest differences among the alternatives are seen). The median elevation in year 2016 under the Basin States Alternative is 1143 feet msl, or 1.6 percent lower than baseline conditions in the same year, with reservoir volume approximate 12 percent lower than baseline conditions and volume becoming slightly greater than baseline by the year 2026 and slightly less than baseline in 2036. By the year 2050 no differences between this alternative and baseline conditions are present.

3.5.3.3.2.5 Flood Control Alternative

Modeling of the Flood Control Alternative produces similar surface elevations, surface area, and volume compared with baseline conditions in the year 2016, with the elevation, surface area and volume becoming slightly greater then baseline by the year 2026 and slightly less than baseline in 2036. By the year 2050 no differences between this alternative and baseline conditions are present.

3.5.3.3.2.6 Six States Alternative

Modeling of the Six States Alternative indicates a Lake Mead surface elevation 1.4 percent lower and a volume 10.6 percent lower than baseline conditions in 2016. By the year 2026 and for the remaining period of analysis, differences between baseline conditions and this alternative are within one percent.

3.5.3.3.2.7 California Alternative

Modeling of the California Alternative indicates a volume of Lake Mead in the year 2016 that is 19 percent lower than baseline conditions, with the difference decreasing to 6.5 percent and 2.2 percent in the years 2026 and 2036, respectively.

3.5.3.3.2.8 Shortage Protection Alternative

Modeling of the Shortage Protection Alternative indicates similar changes in volume reduction as the California Alternative throughout the period of analysis, with volume 19.6 percent lower than baseline conditions in 2016, 6.5 percent lower in 2026 and 2.2 percent lower in 2036.

3.5.3.3.2.9 Summary of Changes in Lake Mead Volume and Elevation

Tables 3.5-6 and 3.5-7 summarize modeled changes in Lake Mead surface elevation, area, and volume under each of the alternatives as compared with baseline conditions. With the exception of the Flood Control Alternative, each of the alternatives indicate an increase potential for lower surface elevations, surface area and lake volume. These difference are most pronounced in year 2016, the end of the interim surplus criteria period. The greatest differences compared with baseline conditions are associated with the California and Shortage Protection alternatives, with intermediate differences indicated by the Basin States and Six States alternatives.

3.5.4 WATER QUALITY BETWEEN HOOVER DAM AND SOUTHERLY INTERNATIONAL BOUNDARY

There have been concerns from the EPA and others about contaminants in the Lower Colorado River between Hoover Dam and the SIB. However, there is little site specific data from this segment of the river. A USGS (1995) study of mercury and other contaminants found in fish and wildlife located in the Yuma Valley area concluded that mercury is not a problem.

The above study also indicates that selenium is also not a problem for fish and wildlife. Selenium in Colorado River water in the Yuma Valley had a median value of less than one micrograms per liter (µg/l). This research also confirms what other previous selenium studies have concluded: selenium in the LCR and its biota remains below the DOI level of concern of five µg/l. A 1986-1987 study by the USGS indicated a finding of 3.4 µg/l or less for dissolved selenium at several sites in the Lower Colorado River (USGS, 1988). Department of Interior's Pre-reconnaissance Investigation Guides (1992) reported similar findings of less than 3.4 µg/l in Colorado River water at Pilot Knob. In the 1995 USGS study of the Yuma area, measured selenium in 18 water samples averaged 1.72 µg/l, with a maximum of 8.0 µg/l and a minimum of less than 1.0 µg/l. Nine of the 18 measurement results were reported to be less than 1.0 µg/l. Currently there are no state fish consumption advisories for mercury, selenium or any other contaminants on the Lower Colorado River (Ketinger, 2000). Water quality studies will continue in this segment of the river during the 15-year period of proposed interim surplus criteria. None of the action alternatives are anticipated to increase concentrations of contaminants beyond the noted limits.

3.6 RIVERFLOW ISSUES

3.6.1 INTRODUCTION

This section considers the potential effects of interim surplus criteria on three types of releases from Glen Canyon Dam and Hoover Dam. The Glen Canyon Dam releases analyzed are those needed for restoration of beaches and habitat along the Colorado River between the Glen Canyon Dam and Lake Mead, and for a yet to be defined program of low steady summer flows to be provided for the study and recovery of endangered Colorado River fish, in years when releases from the dam are near the minimum. The Hoover Dam releases analyzed are the frequency of flood releases from the dam and the effect of flood flows along the river downstream of Hoover Dam.

3.6.2 BEACH/HABITAT-BUILDING FLOWS

The construction and operation of Glen Canyon Dam has caused two major changes related to sediment resources downstream in Glen Canyon and Grand Canyon. The first is reduced sediment supply. Because the dam traps virtually all of the incoming sediment from the Upper Basin in Lake Powell, the Colorado River is now released from the dam as clear water. The second major change is the reduction in the high water zone from the level of pre-dam annual floods to the level of powerplant releases. Thus, the height of annual sediment deposition and erosion has been reduced.

During the investigations leading to the preparation of the *Operation of Glen Canyon Dam Final EIS* (Reclamation, 1995b), the relationships between releases from the dam and downstream sedimentation processes were brought sharply into focus, and flow patterns designed to conserve sediment for building beaches and habitat (i.e., beach/habitat-building flow, or BHBF releases) were identified. The BHBF releases are scheduled high releases of short duration that exceed the hydraulic capacity of the powerplant. Such releases were presented as a commitment in the ROD (Reclamation, 1996e) for the *Operation of the Glen Canyon Dam FEIS*, at a then-assumed frequency of one in five years.

In addition to the BHBF releases described above that exceed the hydraulic capacity of the Glen Canyon Powerplant, the *Operation of Glen Canyon Dam FEIS* identified the need for Beach/Habitat Maintenance Flow releases which do <u>not</u> exceed the hydraulic capacity of the powerplant. These flows were designed to prevent backwater habitat from filling with sediment and to reduce vegetation on camping beaches in years between BHBFs. BHBF releases and Beach/Habitat Maintenance Flows serve as a tool for maintaining a mass balance of sediment in Glen Canyon and Grand Canyon.

3.6.2.1 METHODOLOGY

The frequencies at which BHBF releases from Glen Canyon Dam would occur under baseline conditions and under operation of the interim surplus criteria alternatives were estimated through the use of modeling as described in Section 3.3.

The model was configured to simulate BHBF releases by incorporating the BHBF triggering criteria (contained in Section 3.6.2.2) into the Glen Canyon Dam operating rules. The model was also configured to make no more than one BHBF release in any given year.

3.6.2.2 AFFECTED ENVIRONMENT

Sediment along the Colorado River below Glen Canyon Dam is an important and dynamic resource which affects fish and wildlife habitat along the river, creates camping beaches for recreation, and serves to protect cultural resources. Except for remnants of high river terraces deposited prior to the closure of Glen Canyon Dam, the now limited sediment supply that exists along the river channel is affected by dam operations.

Since construction of Glen Canyon Dam, the measured suspended sediment load (sand, silt, and clay) at Phantom Ranch (in the Grand Canyon) averages 11 million tons per year. Most of this load comes from the Paria River and the Little Colorado River. Flash floods from other side canyons also contribute to the sediment supply (Reclamation, 1995b). The suspended sediment load is sporadic in occurrence, depending on Glen Canyon Dam releases and tributary inputs.

Beneficial sediment mobilization and deposition below Glen Canyon Dam depends on the interaction of two occurrences for full effectiveness: the addition of sediment to the river corridor and BHBF releases. The higher energy of BHBF releases mobilizes suspended and riverbed-stored sand and deposits it as beaches in beach and shoreline areas. Once a BHBF release has been made, additional sediment supply from tributary inflows is needed before subsequent BHBF releases are fully effective in promoting further beach and sandbar deposition along the river.

Subsequent to the ROD cited above, the representatives of the AMP further refined specific criteria under which BHBFs would be made. The criteria provide that under the following two triggering conditions, BHBF releases may be made from Glen Canyon Dam:

1. If the January forecast for the January-July unregulated spring runoff into Lake Powell exceeds 13 maf (about 140 percent of normal) when January 1 content is greater than 21.5 maf; or
2. Any time a Lake Powell inflow forecast would require a monthly powerplant release greater than 1.5 maf.

Research concerning the relationships among dam operations, downstream sediment inflow, river channel and sandbar characteristics, and particle-size distribution along the river is ongoing.

3.6.2.3 ENVIRONMENTAL CONSEQUENCES

The effects of the interim surplus criteria alternatives on BHBF releases from Glen Canyon Dam were analyzed in terms of the yearly frequency at which BHBF releases could be made. Specifically, the frequency was indicated by the occurrence of one or both of the triggering criteria cited above, during a calendar year. The following discussion presents probability of occurrence under baseline conditions, and then compares the probability of BHBF releases under each interim surplus criteria alternative with the baseline conditions.

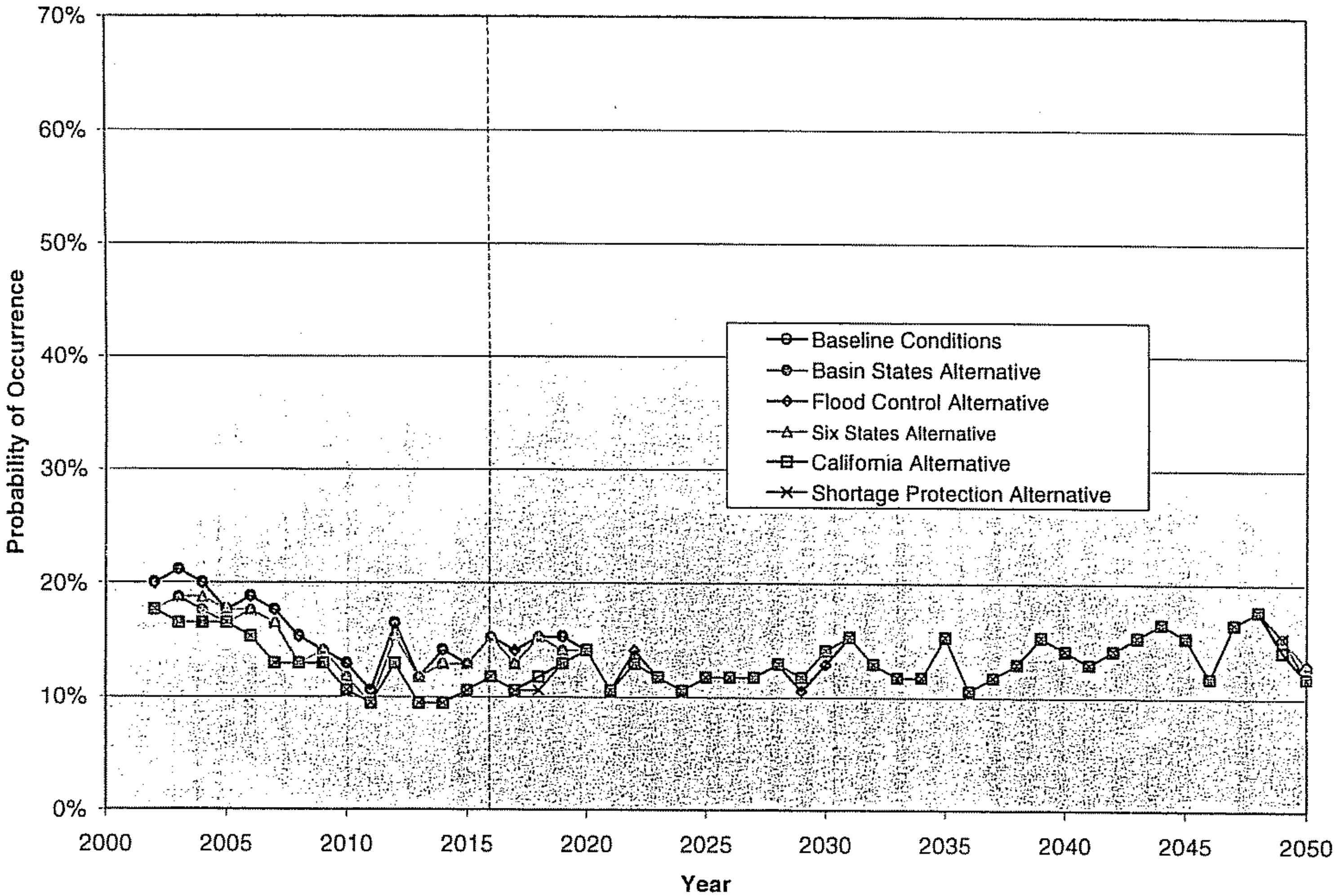
Figure 3.6-1 shows the probabilities that BHBF releases could be made under baseline conditions and the action alternatives. The plots show that the probabilities will decrease over the first decade to an irregular range of approximately 10 to 15 percent or lower, which is maintained until a slight rising trend appears in the last 15 years of the period of analysis. The trends result from the interaction of various factors, including projected increases in depletions by the Upper Division states and the requirements for equalization of storage in Lakes Powell and Mead. The operational parameter most directly comparable to the plotted relationships is the future median water level of Lake Powell. As can be seen on Figure 3.3-6, the median level of the reservoir is projected to recover somewhat in the last 15 years of the period of analysis. This correlates to the slight rise in BHBF release probabilities in the final 15 years.

Table 3.6-1 summarizes the BHBF release probabilities during the interim period and the subsequent period to 2050, based on the data plotted in Figure 3.6-1. The table reflects the higher average probability during the interim period than during the succeeding period ending in 2050.

Table 3.6-1
Probabilities of BHBF Releases from Glen Canyon Dam

	Percent of Time That Conditions Needed for BHBF Releases Would Occur at Lake Powell					
Period	Baseline Condition	Basin States Alternative	Flood Control Alternative	Six States Alternative	California Alternative	Shortage Protection Alternative
Through 2016	15.9%	14.8%	15.9%	14.9%	13.0%	13.0%
2017-2050	13.5%	13.4%	13.5%	13.4%	13.2%	13.2%

Figure 3.6-1
Lake Powell Releases
Probability of Occurrence of BHBF Flows



3.6.2.3.1 Baseline Conditions

During the interim period, the average probability under baseline conditions that BHBF releases could be made in a given year is approximately 15.9 percent, which is equivalent to about one year in six. During the subsequent period ending in 2050, the average probability is approximately 13.5 percent, which is equivalent to about one year in seven. The reduction in probability after 2015 under baseline conditions results from the fact that with time, the Lake Powell water level will probably decline because of increased Upper Basin depletions, as illustrated in Section 3.3. This water level decline would gradually reduce the probability that the BHBF triggering criteria would occur.

3.6.2.3.2 Basin States Alternative

During the interim period, the average probability under the Basin States Alternative that BHBF releases could be made in any single year is approximately 14.8 percent, which equates to approximately one year in seven. During the subsequent period ending in 2050, the average probability is approximately 13.4 percent, which is equivalent to about one year in seven.

3.6.2.3.3 Flood Control Alternative

During the interim period, the average probability under the Flood Control Alternative that BHBF releases could be made in any single year is approximately 15.9 percent, which equates to approximately one year in six. During the subsequent period ending in 2050, the average probability is approximately 13.5 percent, which is equivalent to about one year in seven.

3.6.2.3.4 Six States Alternative

During the interim period, the average probability under the Six States Alternative that BHBF releases could be made in any single year is approximately 14.9 percent, which equates to approximately one year in seven. During the subsequent period ending in 2050, the average probability is approximately 13.4 percent, which is equivalent to about one year in seven.

3.6.2.3.5 California Alternative

During the interim period, the average probability under the California Alternative that BHBF releases could be made in any single year is approximately 13.0 percent, which equates to approximately one year in eight. During the subsequent period ending in 2050, the average probability is approximately 13.2 percent, which is equivalent to about one year in eight.

3.6.2.3.6 Shortage Protection Alternative

During the interim period, the average probability under the Shortage Protection Alternative that BHBF releases could be made in any single year is approximately 13.0 percent, which equates to approximately one year in eight. During the subsequent period ending in 2050, the average probability is approximately 13.2 percent, which is equivalent to about one year in eight.

3.6.3 LOW STEADY SUMMER FLOW

3.6.3.1 AFFECTED ENVIRONMENT

During preparation of the *Operation of Glen Canyon Dam FEIS*, it was hypothesized that steady flows with a seasonal pattern may have a beneficial effect on the potential recovery of special status fish species down stream of Glen Canyon Dam. Accordingly, development of an experimental water release strategy was recommended by the Service to achieve steady flows when compatible with water supply conditions and the requirements of other resources. The strategy included developing and verifying a yet to be defined program of experimental flows which would include providing high steady flows in the spring and low steady flows in summer and fall during water years when a volume of approximately 8.23 maf is released from Glen Canyon Dam. This strategy, commonly referred to as the low steady summer flow program, was contained in the *Final Biological Opinion on the Operation of Glen Canyon Dam* (Service, December 1994c), and recognized in the ROD for the *Operation of Glen Canyon Dam FEIS* (USDI, 1996).

3.6.3.2 ENVIRONMENTAL CONSEQUENCES

The ability to test the low steady summer flow release strategy at Glen Canyon Dam according to the ROD could be affected by the implementation of interim surplus criteria. This matter was investigated by analyzing the model releases from Glen Canyon Dam to determine the probabilities at which minimum releases of 8.23 maf per water year would occur.

Figure 3.6-2 shows the annual probabilities of minimum releases from Glen Canyon Dam during the period of analysis. Note that the first year plotted is 2003, since 2003 would be the first complete water year (October 1, 2002 through September 30, 2003) during the interim period. The plots show that the probabilities increase through 2023, from approximately 20 to 25 percent to approximately 60 percent, which is maintained until another increase to 67 percent occurs during the last 15 years of the analysis. The trends result from the interaction of various factors that affect annual releases from Glen Canyon Dam, including projected increases in depletions by the Upper Division states and the requirements for equalization of storage in Lakes Powell and Mead.

Figure 3.6-2
Lake Powell Releases
Probability of Approximately 8.23 maf Annual Release

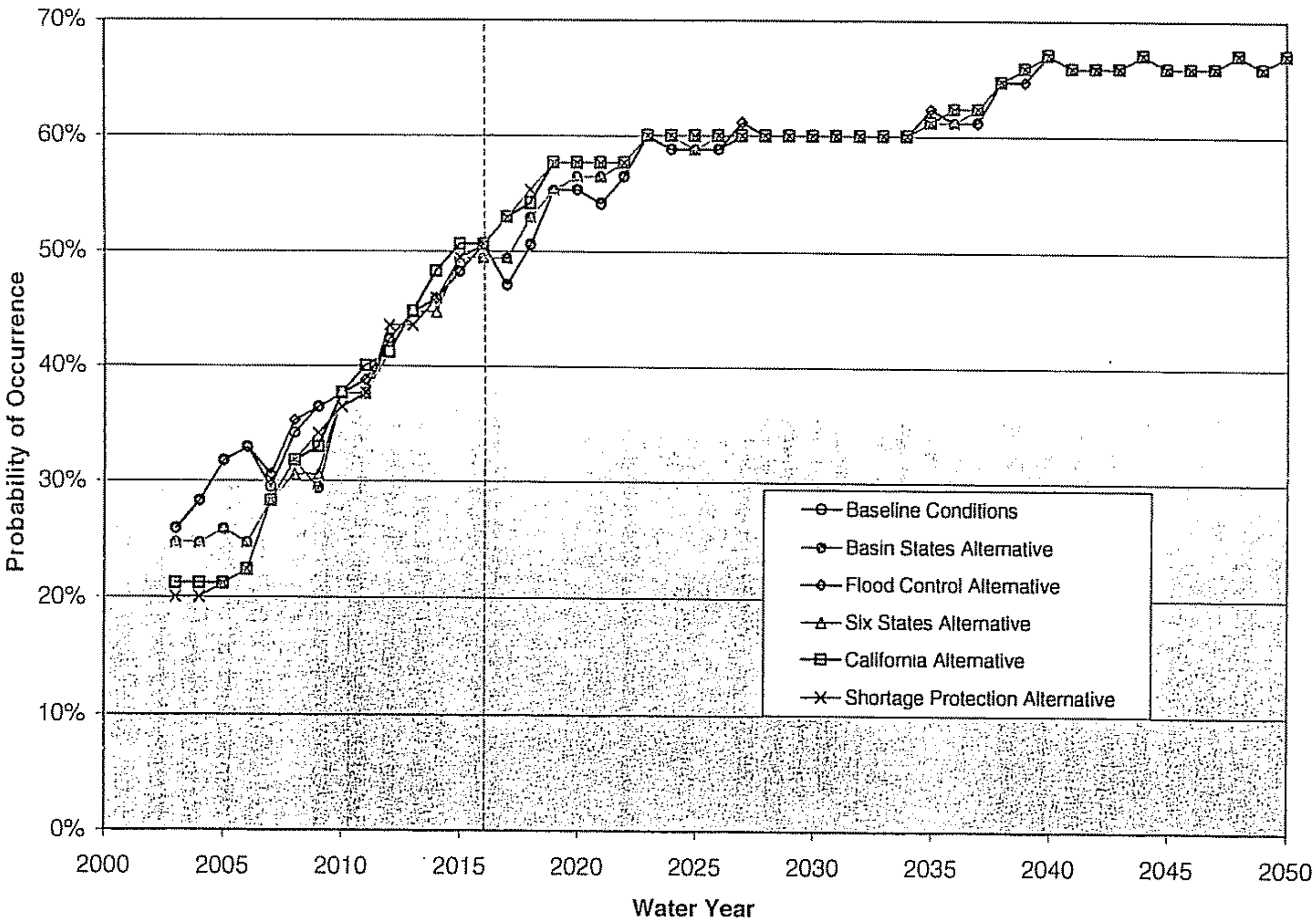


Table 3.6-2 summarizes the probabilities that minimum releases would occur during the interim period and the subsequent period to 2050, based on data plotted in Figure 3.6-2. Probabilities are summarized by water year because releases from Glen Canyon Dam are accounted for by water year under provisions of the LROC. The results indicate that under baseline conditions, the probability of 8.23 maf annual releases from the dam is approximately 38.2 percent during the interim period and 61.6 percent during the subsequent period ending in 2050. The probabilities under all alternatives are similar to those under baseline conditions after 2006. Under the Flood Control Alternative, the probability is approximately the same as for baseline conditions, as shown on Table 3.6-2. The probabilities under the remaining four interim surplus criteria alternatives during the interim period are one to two percent less than under baseline conditions. During the subsequent period through 2050, the probabilities resulting from the remaining four surplus criteria would be one to two percent higher than under baseline conditions.

Table 3.6-2
Probability of Minimum Glen Canyon Dam Releases
(Annual Releases of 8.23 maf)

Period (Water Years)	Baseline Condition	Basin States Alternative	Flood Control Alternative	Six States Alternative	California Alternative	Shortage Protection Alternative
Through 2016	38.2%	36.3%	38.4%	36.2%	35.8%	36.3%
2017-2050	61.6%	61.9%	61.6%	61.9%	62.2%	62.1%

Note: The "water year" on which this accounting is based extends from October 1 to September 30.

3.6.4 FLOODING DOWNSTREAM OF HOOVER DAM

Under the BCPA, flood control was specified as the project purpose having first priority for the operation of Hoover Dam. Subsequently, Section 7 of the Flood Control Act of 1944 established that the Secretary of War (now the Corps) will prescribe regulations for flood control for projects authorized, wholly or in part, for such purposes.

The Los Angeles District of the Corps published the current flood control regulations in the *Water Control Manual for Flood Control, Hoover Dam and Lake Mead Colorado River, Nevada and Arizona* (Water Control Manual) dated December 1982. The Field Working Agreement between Corps and Reclamation for the flood control operation of Hoover Dam and Lake Mead, as prescribed by the Water Control Manual, was signed on February 8, 1984. The flood control plan is the result of a coordinated effort between the Corps and Reclamation; however, the Corps is responsible for providing the flood control regulations and has authority for final approval. The Secretary is responsible for operating Hoover Dam in accordance with these regulations. Any deviation from the flood control operating instructions must be authorized by the Corps.

This analysis addresses the flooding that occurs along the Colorado River below Hoover Dam. The evaluation focuses on the change in the probability that various "threshold" flows would be released from Hoover, Davis and Parker Dams. A threshold flow rate is one at which flood damages have been found to begin to occur along the river. The analysis is not limited to dam releases made expressly in connection with flood control operation, but also includes releases made for water supply and power generation purposes. For example, power generation requirements can cause releases from Hoover Dam to exceed 19,000 cfs, with such releases being regulated in Lake Mohave downstream. In addition, the analysis presents data on land use and anticipated flood damages that were developed by the Los Angeles District Corps of Engineers in the *Review of Flood Control Regulations, Colorado River Basin, Hoover Dam, July 1982* (Corps, 1982).

3.6.4.1 AFFECTED ENVIRONMENT

Historical flows downstream of Hoover Dam have caused flood damages at various points along the lower Colorado River. A key threshold level was established as a result of flooding that occurred in 1983 when uncontrolled releases occurred over the Hoover Dam spillways. The high Colorado River flows caused damages primarily to encroachments in the Colorado River floodplain. In addition, several lower thresholds that are significant along various reaches are evaluated in the following subsections.

The Colorado River Floodway Protection Act (Floodway Act) originated from Congressional hearings held in 1983 following the flood. The Floodway Act called for the establishment of a federally declared floodway from Davis Dam to the SIB. The floodway is to accommodate either a 1-in-100 year river flow consisting of controlled releases and tributary inflow, or a flow of 40,000 cfs, whichever is greater. As discussed in Section 3.3.1, certain flood release rates from Hoover Dam are required depending on flood flow into Lake Mead and the amount of available storage space.

Estimates of development in the flood plains below Hoover Dam were last made by the Corps based on 1979 data (Corps, 1982). These data are presented in Table 3.6-3.

3.6.4.1.1 Hoover Dam to Davis Dam

Critical flood flows for the reach between Hoover Dam and Davis Dam are 19,000 cfs, 28,000 cfs, 35,000 cfs, 43,000 cfs, and 73,000 cfs.

3.6.4.1.2 Davis Dam to Parker Dam

The river is within levees for most of the reach from Davis Dam to Parker Dam. Historical flood flows have caused damage to some of the bank protection. Minor damage begins to occur at flows of 26,000 cfs.

Table 3.6-3
Development in Flood Plains Between Hoover Dam and SIB, 1979 Data[1]

	(Number of structures unless otherwise noted)					
Flood Flow (cfs)	Mobile Homes	Residential	Commercial/ Industrial	Public/ Semipublic	Agriculture (acres)	Recreation Facilities [5]
100,000	1,609	1,457	74	70	55,089	278
71,000[2]	758	786	54	66	15,861	277
48,000[3]	164	198	13	10	2,671	277
38,000[4]	101	138	4	6	176	232
28,000	17	44	1	0	90	201

[1] Corps of Engineers, Colorado River Basin Hoover Dam, Review of Flood Control Regulations, Final Report, July 1982, Table C-1.
[2] 78,000 cfs at Needles
[3] 50,000 cfs at Needles
[4] 40,000 cfs at Needles
[5] Recreation facilities are primarily boat docks that would sustain significant damage with high flows.

3.6.4.1.3 Hoover Dam to Davis Dam

Critical flood flows for the reach between Hoover Dam and Davis Dam are 19,000 cfs, 28,000 cfs, 35,000 cfs, 43,000 cfs, and 73,000 cfs.

3.6.4.1.4 Davis Dam to Parker Dam

The river is within levees for most of the reach from Davis Dam to Parker Dam. Historical flood flows have caused damage to some of the bank protection. Minor damage begins to occur at flows of 26,000 cfs.

3.6.4.1.5 Parker Dam to Laguna Dam

Below Parker Dam, significant damage to permanent homes has occurred during releases within the flood operation criteria. This area has been further developed since the flood operations in 1983. Minor damage begins at 19,000 cfs along the Parker Strip (the reach of river between Parker Dam and the town of Parker, Arizona). Backwater regions, which function as wildlife refuges and recreational areas, accumulated sediment, and in some cases, became isolated from the Colorado River. Historical flood flows have also resulted in damage to infrastructure of government agencies.

3.6.4.1.6 Laguna Dam to SIB

Below Laguna Dam, the banks of the Colorado River are not protected. Historical flood flows have resulted in significant damage to the banks. Associated increases of groundwater level in the Yuma area have also resulted in some lands becoming water logged and caused drains to cease functioning. During the scoping process for this

DEIS, a letter from the Yuma County Water Users' Association states that "[o]ur landowners are harmed by such releases, particularly should the flood control releases be required to go beyond the 19,000 cubic feet per second Hoover release level" (Pope, 1999). The letter indicates that a flood control release of 28,000 cfs or greater could result in upwards of $200 million in damages to the Yuma area. Other injured parties could include the City of Yuma, the County of Yuma, Cocopah Indian Tribe, the Gila Valley, Bard Irrigation District, and the Quechan Indian Tribe.

Additional flows of concern include:

- Laguna Dam south to Pilot Knob: 9,000 cfs is the threshold value. Flows of 10,000 cfs to 11,000 cfs impact leach fields of trailer parks located within levees.
- Pilot Knob to SIB: 15,000 cfs is a threshold value. Above that level, high groundwater, localized crop damage and damage to the United States Bypass Drain occur.

3.6.4.2 ENVIRONMENTAL CONSEQUENCES

The effects of the interim surplus criteria on flood flows were analyzed by determining the probabilities that releases from Davis and Parker Dams would reach or exceed certain flow rates that have been found to be thresholds for damages. In addition, the analysis addressed the probabilities that releases of various magnitudes would be made from Hoover Dam corresponding to the required flood control releases discussed in Section 3.3.1.2, Operation of Hoover Dam. The release probabilities were determined from results of river system modeling described in Section 3.3. The results of the analysis are shown in Table 3.6-4.

The results portrayed on Table 3.6.3 show that except for the Flood Control Alternative, the action alternatives would reduce the probability of flows at or above the damage thresholds.

The Corps estimated the likely damage to development based on the 1979 land use data (Corps, 1982). These data are presented in Table 3.6-5.

The data on direct, physical damages presented in Table 3.6-5 are based on simultaneous flooding along all reaches of the river from Hoover Dam to the SIB. The data show that damages increase much more rapidly than the size of the flow. For example, a 48,000-cfs flow has 15 times the impact of a 22,000-cfs flow, while the flow increases by only 2.2 times. A 48,000 cfs flow has a less than one-in-500 probability of occurring in any one year, while a 22,000 cfs flow has a greater than one-in-20 probability of occurring in any one year under all alternatives.

Table 3.6-4
Discharge Probabilities from Hoover, Davis and Parker Dams

Release Point	Discharge (cfs)[1]	Percent of Years With Flows Greater Than or Equal to Discharge					
		Baseline Conditions	Basin States Alternative	Flood Control Alternative	California Alternative	Six States Alternative	Shortage Protection Alternative
Years 2002 to 2016							
Hoover Dam	19,000	20.8	18.8	21.2	16.3	18.6	16.9
Hoover Dam	28,000	7.5	7.2	7.7	5.5	7.1	5.8
Hoover Dam	35,000	2.1	2.0	2.1	1.6	2.0	1.7
Hoover Dam	40,000	0.2	0.2	0.2	0.2	0.2	0.2
Hoover Dam	73,000	0.0	0.0	0.0	0.0	0.0	0.0
Davis Dam	26,000	8.6	8.1	9.1	7.0	8.0	7.1
Parker Dam	19,500	10.4	9.4	11.3	7.8	9.3	8.0
Years 2017 to 2050							
Hoover Dam	19,000	14.6	14.1	14.9	13.9	14.1	13.8
Hoover Dam	28,000	4.0	3.8	4.2	3.7	3.8	3.6
Hoover Dam	35,000	0.9	1.7	0.9	0.8	0.9	0.8
Hoover Dam	40,000	0.2	0.1	0.2	0.1	0.2	0.1
Hoover Dam	73,000	0.0	0.0	0.0	0.0	0.0	0.0
Davis Dam	26,000	4.8	4.6	5.0	4.4	4.6	4.5
Parker Dam	19,500	5.9	5.7	6.1	5.6	5.7	5.6

[1] Average monthly discharge

Table 3.6-5
Estimated Flood Damages Between Hoover Dam and the SIB
(1979 level of development and 2000 price level[1])

Flood Flow (cfs)	Flood Damages
100,000	$201,000,000
71,000 [2]	$ 55,700,000
48,000[3]	$ 9,210,000
38,000[4]	$ 1,550,000
22,000	$ 610,000

[1] Corps of Engineers, Colorado River Basin Hoover Dam, Review of Flood Control Regulations. Final Report, July 1982. Table C-5 Adjusted from June 1978 to March 2000 price level by Consumer Price Index-all Urban Consumers (June 1978 is 65.2, March 2000 is 167.8, Adjustment factor: 2.57)

[2] 78,000 cfs at Needles

[3] 50,000 cfs at Needles

[4] 40,000 cfs at Needles

3.7 AQUATIC RESOURCES

3.7.1 INTRODUCTION

The analyses presented in this section consider two specific issues associated with aquatic resources. These issues are potential effects to Lake Mead and Lake Powell aquatic species habitat and potential effects to sport fisheries at Lake Powell, Lake Mead, and the Colorado River between Lake Powell and Lake Mead. The interim surplus criteria are not expected to result in any changes to aquatic resources below Hoover Dam.

3.7.2 LAKE HABITAT

The primary lake habitats identified for potential affect within the project area include Lake Powell and Lake Mead. Other reservoirs downstream of Lake Mead (Lake Mohave and Lake Havasu) are not expected to be affected by the proposed interim surplus criteria because operation of the system keeps lake levels at specified target elevations to facilitate power generation and water deliveries (Reclamation, 2000).

Native Colorado River fishes have not fared well in the reservoirs. Non-native fish species, which prey on and compete with native species, have become well-established in both lakes. While some native species may spawn within the reservoirs and others have young that drift into the lakes, predation and competition is believed to eliminate young native fish from the reservoirs and precludes their survival and recruitment. A discussion of native Colorado River fishes is presented in Section 3.8, Special-Status Species.

3.7.2.1 METHODOLOGY

Existing literature was reviewed to determine the historic and current status of fish assemblages in Lake Powell and Lake Mead. Literature reviewed included recent publications and draft documents on the operations at Lake Powell and Lake Mead, biological assessments, fish management plans, and biological opinions. Investigation into critical lake elevations, water quality, and temperature limits were made based on the fish species known to inhabit these lakes, including the use of these lakes by endangered species. Because no "threshold" lake elevations associated with significant adverse effects on lake habitat were identified for any of the fish species, the use of system modeling relied upon a comparison of general reservoir surface elevation trends under baseline conditions and the alternatives, shown in Figures 3.3-6 and 3.3-13. A qualitative analysis of potential lake habitat changes was made by comparing the differences between lake level trends under baseline conditions and the various alternatives.

3.7.2.2 AFFECTED ENVIRONMENT

3.7.2.2.1 Lake Powell

Aquatic habitat in Lake Powell is a result of the lake's physical and geographical characteristics. Lake Powell has a surface area of 255 square miles and contains up to 24.3 maf of active storage. At full pool, depth of the reservoir near the dam is 561 feet. The thermocline (the boundary layer between a strata of colder and warmer water) changes seasonally, but below approximately 150 feet deep, the cold hypolimnion (a low oxygen, low light, deep water layer of the lake) is consistently maintained due to thermal and chemical properties. Lake Powell exhibits a trophic gradient from the shallow productive inflows where nutrients and sediments are delivered by rivers, to the clear nutrient-poor water by the dam. As the reservoir gradually shallows moving away from the dam, the depth and extent of the thermocline and hypolimnion change. Lake elevations change from year to year depending on numerous factors, including Upper Basin runoff. The clear water reservoir offers habitat beneficial to non-native fish. Generally, the reservoir is oligotrophic (characterized by low dissolved nutrients and organic matter); deep, clear, and low in chlorophyll abundance (NPS, 1996).

Non-native fish species became established by intentional and unintentional introductions. Largemouth bass and crappie populations were stocked initially and subsequently proliferated to provide the bulk of the sport fisheries. Both species have declined in recent years due to lack of habitat structure for young fish. Filling, fluctuation, and aging of the reservoir resulted in changing habitat that eliminated most of the vegetation and favored different species. The habitat change led to the introduction of smallmouth bass and striped bass, presently the two dominant predator species in the reservoir, with striped bass being the most dominant. Threadfin shad were introduced to provide an additional forage base and quickly became the predominant prey species (NPS, 1996).

Other species common in Lake Powell include walleye, bluegill, green sunfish, carp and channel catfish. Species that occur in the reservoir, but that are mainly associated with tributaries and inflow, include fathead minnow, mosquitofish, red shiner and plains killifish (NPS, 1996). Table 3.7-1 lists fish species present in the project area.

Native fish species were displaced by habitat loss and alteration associated with construction and operation of mainstream dams and reservoirs, as well as competition with and predation by introduced non-native species. Bonytail is the native species believed to be in the most peril of imminent extinction because they are virtually eliminated in the Upper Basin. Bonytail were reported in Lake Powell soon after closure of Glen Canyon Dam; however, annual gill-net surveys conducted by the Utah Department of Wildlife Resources have failed to produce any bonytail in the last 20 years.

Table 3.7-1
Fish Species Present in the Project Area

Species	Scientific Name	Origin
Black bullhead	*Ictalurus melas*	Invading sport fish
Black crappie	*Pomoxis nigromaculatus*	Introduced sport fish
Bluegill	*Lepomis macrochirus*	Invading sport fish
Bluehead sucker	*Catastomus discobolus*	Native to Colorado River
Bonytail	*Gila elegans*	Native to Colorado River
Brown Trout	*Salmo trutta*	Introduced sport fish
Carp	*Cyprinus carpio*	Invading fish
Channel catfish	*Ictalurus punctatus*	Invading sport fish
Colorado pikeminnow	*Ptychocheilus lucius*	Native to Colorado River
Fathead minnow	*Pimephales promelas*	Invading forage fish
Flannelmouth sucker	*Catostomus latipinnis*	Native to Colorado River
Green sunfish	*Lepomis cyanellus*	Invading fish
Humpback chub	*Gila cypha*	Native to Colorado River
Largemouth bass	*Micropterus salmoides*	Introduced sport fish
Mosquitofish	*Gambusia affinis*	Invading forage fish
Northern pike	*Esox lucius*	Invading sport fish
Rainbow trout	*Oncorhynchus mykiss*	Introduced sport fish
Razorback sucker	*Xyrauchen texanus*	Native to Colorado River
Red shiner	*Notropis lutrensis*	Invading forage fish
Roundtail chub	*Gila robusta*	Native to Colorado River
Smallmouth bass	*Micropterus dolomieui*	Introduced sport fish
Speckled dace	*Rhinichthys osculus*	Native to Colorado River
Spotted sculpin	*Cottus bairdi*	Native to Colorado River
Striped bass	*Morone saxatilis*	Introduced sport fish
Threadfin shad	*Dorosoma petenense*	Introduced forage fish
Walleye	*Stizostedion vitreum*	Invading sport fish

Other native species that may still persist in Lake Powell include the Colorado pikeminnow and humpback chub. Although there have been no reports of Colorado pikeminnow in the lake since 1977, they are believed to still inhabit the Colorado River inflow area. Very few humpback chub have been found in Lake Powell and it is presumed that they are not present in the lake at this time; however, unidentified chub species were collected by seines and light traps in the Colorado River inflow area (NPS, 1996). Small numbers of razorback suckers have persisted in Lake Powell since the closure of Glen Canyon Dam, occurring mainly near the inflow of the San Juan River. Flannelmouth suckers are probably the only native fish to inhabit the main body of Lake Powell in detectable numbers. However, there has been a declining trend in population size and reproductive recruitment has not been documented. Additional discussion of special-status fish species is included in Section 3.8.

3.7.2.2.2 Lake Mead

Lake Mead has a surface area of 245 square miles and a storage capacity of 26 maf. Over two-thirds of the volume of Lake Mead remains at 55°F (13°C) throughout the year, resulting in a constant, cool discharge at Hoover Dam (USBR, 1996d). At full pool, depth of the reservoir near the dam is approximately 550 feet. Because of its physical similarity to Lake Powell, the limnological characteristics of Lake Mead are also similar. The thermocline changes seasonally and a cold hypolimnion is consistently maintained due to thermal and chemical properties. Surface elevations change from year to year depending on numerous factors, including Upper Basin runoff. The clear water reservoir offers habitat beneficial to non-native fish.

Native fish species were displaced by habitat loss and alteration associated with construction and operation of mainstream dams and reservoirs, as well as competition and predation with introduced non-native species. Razorback sucker, federally listed as an endangered species, is the only native species that maintains a remnant population in Lake Mead (USBR, 1996a,b).

Non-native fish species became established by intentional and unintentional introductions. Introduced fish species found in Lake Mead include largemouth bass, striped bass, rainbow trout, channel catfish, crappie, threadfin shad and carp (USBR, 1996). Bonytail populations are supported by specific management activities designed to re-establish this species in Lake Mohave. Remnant populations of these species exist downstream of Lake Mead in Lake Mohave and Lake Havasu and groups such as the Native Fish Wok Group (NFWG) and Lake Havasu Fishery Improvement Project (HAVFISH) are currently engaged in activities conducted under Section 7(a)(I) of the ESA to aid in the conservation and recovery of these species in the lower Colorado River Basis (USBR, 1999).

Releases from Lake Mead are the predominant influence on inflows to two other reservoirs, Lake Mohave and Lake Havasu. Operations at Lake Mead typically keep lake elevations at the downstream reservoirs at specific target elevations to facilitate power generation and water deliveries. The operation of Lake Mohave through 2002 is anticipated to limit reservoir fluctuations as a measure to assure that potential impacts to razorback sucker will be minimized during the spawning season (USBR, 1996).

3.7.2.2.3 General Effects of Reservoir Operation

Lake habitat in both Lake Powell and Lake Mead consists primarily of deep, clear, open water habitats with a cold hypolimnion that is consistently maintained due to thermal and chemical properties. The habitat found in these lakes is drastically different from the riverine habitat that existed prior to the construction of the dams, and is more suitable for non-native species than native species. Non-native fish species were introduced into the lakes, and subsequently established naturally reproducing populations. Habitat changes resulting from fluctuating lake levels have favored introduced species tolerant of the conditions and temperatures found in the lakes. These species are able to reproduce in the lakes and are not expected to be affected by fluctuating lake levels. In Lake Powell for example, striped bass have experienced "unprecedented natural reproduction and survival" that allowed them to become "the most numerous sport fish and dominate the fish community of Lake Powell" (NPS, 1996).

The ability of native species to adapt to the lake habitat is limited mainly by the decreased survival of eggs and the lack of recruitment of young individuals into the adult population. The primary reason for low recruitment of native fish is predation of eggs and young by the established populations of non-native species. In some cases, nutrition may also influence recruitment (Horn, June 2000).

3.7.2.3. ENVIRONMENTAL CONSEQUENCES

There are no specific "threshold" lake levels that are definitive for evaluation of potential impacts to lake habitat in Lake Powell or Lake Mead. Projections of Lake Powell and Lake Mead surface the elevations are discussed in Sections 3.3.4.2 and 3.3.4.4, respectively. These reservoirs will continue to be subjected to varying inflows and fluctuating surface elevations, primarily due to hydrologic conditions present in the watershed and increasing water use in the Upper Basin. Historically, reservoir conditions have resulted in lake habitat that is favorable to non-native species and unfavorable to native species. Because the projected declines in reservoir surface elevation in both Lake Powell and Lake Mead are within the normal operational range of fluctuations, they are not likely to result in substantial changes to lake habitat.

3.7.3 SPORT FISHERIES

This section considers potential effects of the interim surplus criteria alternatives on sport fisheries in Lake Powell, Lake Mead and below Hoover Dam. Potential effects on recreation associated with sport fisheries are discussed in Section 3.9.5.

The sport fishery within the Colorado River corridor from Glen Canyon Dam to Separation Canyon is not analyzed in detail in this FEIS because annual release patterns from Glen Canyon Dam are determined in accordance with the 1996 ROD and are monitored through the Glen Canyon Dam Adaptive Management Program. Through this process, the effects of dam operations on downstream resources, including sport fish, are monitored and studied. The results are used to formulate potential recommendations on refinements to dam operations, to ensure that the purposes of the Grand Canyon Protection Act are met.

The possibility of changes in river water temperature downstream of Hoover Dam was also investigated. Reclamation conducted an analysis predicting water temperatures downstream of Hoover Dam with a Lake Mead water surface elevation of 1120 feet msl and a steady release of 62,000 cfs (30 percent higher than powerplant capacity). Under these conditions, the warmest temperature predicted was 58.5°F in late summer. The midsummer discharge temperature was predicted to be 58.5°F (Reclamation, 1991). Under actual conditions with a reservoir elevation of 1120 feet msl, however, maximum discharge would be equal to the powerplant capacity of 49,000 cfs. At this lesser flow, discharges would be cooler than the temperatures predicted in the analysis, since less discharge water would be drawn from the warm upper portion of the reservoir than at higher flows. Therefore, it is assumed that increases of release temperatures corresponding to the median decline of lake levels under baseline conditions and the action alternatives would result in temperatures less than those predicted in the 1981 analysis.

Staff from the Willow Beach Federal Fish Hatchery, located about 12 miles downstream of Hoover Dam, reported that over the long term, river water temperatures have typically ranged from 56°F to 58°F, with occasional lows of 54°F. Modeled Hoover Dam discharges are not significantly different from those during periods when water temperatures were measured by hatchery personnel. It is expected that the minor changes in river water temperature described above would not be expected to adversely affect fish populations or the sport fishery in the river below Hoover Dam. The hatchery rears both trout and native fish. For native species, the hatchery warms the river water with solar panels. The projected increase in river temperatures may be a benefit to the hatchery's native fish program. River temperatures are not addressed further in this section.

3.7.3.1 METHODOLOGY

Existing literature was reviewed to determine the historic and current status of sport fish assemblages in Lake Powell and Lake Mead. Literature reviewed included recent publications on the status of sportfishing in both reservoirs, along with a review of water quality data including limnological reports and journal articles for information on contaminants found within the lakes and in fish tissue. Potential effects on sport fisheries identified herein are based on the analysis of lake habitat discussed in Section 3.7.2. Potential effects on sport fisheries are based on model output showing general trends of reservoir surface elevations, river flow rates and temperature. No specific threshold elevations or flows are used in the analysis.

3.7.3.2 AFFECTED ENVIRONMENT

Currently, Lake Powell and Lake Mead provide habitat for numerous species of introduced (non-native) fish which support outstanding recreational sport fishing opportunities. The fish species present in the GCNRA are listed in Table 3.7-1.

A similar species assemblage exists for Lake Mead. The two most common sportfish species found in Lake Powell and Lake Mead are striped bass and largemouth bass.

3.7.3.2.1 Reservoir Sport Fisheries

The primary sport fisheries management challenge in the reservoirs is trying to stabilize a striped bass population that reproduces beyond the limits of available forage. As a result of unlimited striped bass reproduction, pelagic (open water) stocks of threadfin shad upon which they prey have been decimated. Decimation of the shad population then results in striped bass starvation. Reduction of striped bass numbers allows the shad population to rebound from adult stocks residing in turbid, thermal refuges where they are less vulnerable to striped bass predation. As shad reenter the pelagic zone in large numbers, they are subsequently eaten by young striped bass who grow rapidly, mature, and once again eliminate shad from the pelagic zone. This widely fluctuating predator-prey cycle occurred during the 1990s and still occurs today.

Threadfin shad in Lake Powell exist in the northernmost portion of their range. Lower lethal temperatures for shad are reported as 40°F to 41°F (4.5°C to 5°C). Shad currently survive winters where water temperatures consistently range near the lethal limit by seeking deep strata where the water temperature is warmer and stable. An additional temperature reduction of even 2°F (1.0°C) may remove the thermal refuge and result in loss of shad over winter. The absence of a pelagic forage fish would not eliminate striped bass, which now subsist on plankton for the first year or two of life, but would eventually result in a permanently stunted striped bass population without quality sport fishing value (NPS, 1996).

The sport fishery at Lake Mead has been managed in much the same manner as in Lake Powell and has resulted in many of the same management challenges. The introduction of threadfin shad as a forage species and striped bass as the main predator has produced similar interactions between the two species.

3.7.3.3 ENVIRONMENTAL CONSEQUENCES

3.7.3.3.1 Reservoir Sport Fisheries

The sport fishery in Lake Powell and Lake Mead is primarily based on the presence of striped bass. Other sport fish found in the lakes include largemouth bass, catfish and trout. Since the predator-prey relationship between striped bass and threadfin shad can result in large variations of the striped bass population, stabilizing the population of striped bass and maintaining the threadfin shad population is an ongoing challenge to sport fish management in the lakes.

Although the occurrence of prey base fluctuations is more directly related to striped bass populations, a thermal refuge for adult threadfin shad is critical. Under baseline conditions and each of the alternatives, the challenge of stabilizing striped bass and threadfin shad populations in the lakes will continue and may include the need to alter the size or catch limit of striped bass or planting of fish from hatchery stock. All of the other sport fish, with the possible exception of trout, are well-adapted to habitats found in the lakes and are largely unaffected by fluctuating lake levels and water temperatures. Trout populations in the reservoirs are sustained by planting fish from hatchery stock.

3.7.3.3.2 Colorado River Sport Fisheries

The primary sport fish in the Colorado River between Glen Canyon Dam and the Lake Mead inflow is rainbow trout. Natural reproduction of rainbow trout in the Grand Canyon is dependent on cool water temperatures, access to tributaries for spawning and continued availability of suitable main stem habitat. These variables are directly related to patterns of flow releases from Lake Powell. Under baseline conditions and each of the alternatives, an increase in the temperature of water released from Glen Canyon Dam could occur if reservoir levels in Lake Powell fall below an elevation of 3590 feet msl. The probability of elevations below 3590 feet msl is limited to the 10 percentile rankings and is not projected to occur until approximately years 2018 to 2028. Water releases from Glen Canyon Dam are controlled by operating criteria contained in the 1996 ROD and are monitored for compliance with the Grand Canyon Protection Act through the Adaptive Management Program. As a result, Colorado River sport fisheries would not be affected by the interim surplus criteria alternatives.